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Nitrates.—Nitric acid combines with one equivalent of the various bases to form the class of salts termed nitrates. No acid nitrates exist or have been produced, but several subnitrates may be formed; that is to say, salts may be obtained containing more than one base for each equivalent of acid; such, for instance, as the subnitrate of copper, $3\text{ Cu O}, \text{NO}_5, \text{HO}$. When heated, most of the nitrates fuse readily; at an elevated temperature they are all decomposed, and in most cases the pure oxide remains. When thrown on glowing coals, the nitrates are decomposed with scintillation; if dissolved in water, and paper be moistened with the solution, allowed to dry, and then burned, the smouldering combustion characteristic of touch-paper will be produced. This property, however, is also exhibited by the salts of some other acids, of which the chloric is the most important.

Adulterations.—The specific gravity of nitric acid is very often artificially augmented by dissolving in it nitrate of potassa; this sophistication, however, is very easily detected by evaporating the acid, when the nitrate so added will be left behind. But the best way of determining the real value of nitric acid is by ascertaining its saturating capability, that is, finding how much pure carbonate of soda it will neutralize.

The nitric acid of commerce is ordinarily contaminated by *sulphuric* and *hydrochloric acids*, or by *chlorine* or *chlorides*.

The presence of sulphuric acid is discovered by diluting a portion of the nitric acid with pure water, and adding a solution of nitrate of baryta; if this produces a white precipitate, insoluble in water, in acids, and likewise in ammonia, it is sulphate of baryta, and it indicates, of course, the presence of *sulphuric acid*. If the precipitate is in ponderable quantities, it should be first boiled with the acid liquor in which it has been produced, allowed to settle, filtered, washed, dried, ignited, and weighed: 116.5 grains represent forty of dry sulphuric acid.

The presence of *chlorine* or of *chlorides*, or of *hydrochloric acid*, is detected by diluting the nitric acid with pure water, and adding a solution of nitrate of silver. If a white curdy precipitate, or an opaline tinge or turbidity is produced, insoluble in nitric acid, but which instantly disappears by pouring an excess of ammonia, and reappears by adding an excess of acid, it is chloride of silver; in which case the acid liquor should be moderately heated, in order to promote the settling of the precipitate, which may then be collected on a filter as small as possible, washed, and carefully exsiccated. It should then be introduced into a counterpoised porcelain crucible; the filter, being scraped clean, is afterwards burnt upon the cover of the crucible, and the ashes are added to the precipitate in the crucible; the mass is then fused, and on cooling, it is weighed; 143.5 grains of chloride of silver represent 35.5 grains of chlorine, or 36.5 grains of hydrochloric acid.

Before testing the acid, as just said, it must not be forgotten to dilute it with three or four times its bulk of distilled water, for otherwise a precipitate would be produced, but which is nothing else than nitrate of baryta and nitrate of silver, which might simulate the presence of sulphuric acid and of chlorine. Such pre-

cipitates, however, immediately disappear by an addition of water.

When nitric acid contains fixed substances, they are easily detected by evaporating a small quantity of the acid in a watch-glass or small capsule, in which case a fixed residuum will be left. Pure nitric acid is entirely volatilizable by heat.

Impure nitric acid can always be easily purified by adding to it a sufficient quantity of nitrate of silver, in order to precipitate the chlorine and sulphuric acid, decanting the acid from the precipitates produced, and distilling it in a glass retort and glass receiver, taking care not to use either lute or cork. If done with care, and at a moderate heat, the acid which passes is pure and colorless.

Physiological Effects.—The action of this acid varies with its degree of concentration or dilution. In the concentrated form, the acid acts as a powerfully corrosive poison, which property it partly derives from its affinity for water, but more especially from the facility with which it gives out oxygen; so that the appearances caused by its action on some of the tissues are different from those produced by sulphuric acid. The permanent yellow stain—xanthoproteic acid—which it communicates to the cuticle, is peculiar to it. Iodine stains the skin yellow or brown, but a little caustic potassa quickly removes the color, when recent; whereas the yellowish stain caused by nitric acid becomes orange, on the addition of an alkaline soap. Bromine also stains the skin yellow; but, when recently produced, the color may likewise be removed by potassa. The yellow or citron tint communicated to the lining membrane of the tongue, pharynx, *et cetera*, by nitric acid, has been lucidly illustrated by Dr. ROUPELL. A preparation presenting appearances in every way identical, is preserved in the anatomical museum of the metropolitan hospital. Nitric, like sulphuric acid, also chars the animal tissues; and thus, after the ingestion of it, the stomach is sometimes found blackened, as if sulphuric acid had been swallowed. The symptoms are the same as those produced by sulphuric acid. The yellow, citron, or orange spots sometimes seen on the lips, chin, or face, will, when present, at once indicate the kind of acid swallowed. Sometimes the binoxide of nitrogen is evolved by the mouth.

Properly diluted, nitric acid produces effects similar to those of the other mineral acids. It is said, however, to act less evidently as a tonic, and to be more apt to disagree with the stomach, so that it cannot be used for so long a time. In some instances it has excited ptyalism, and from this circumstance, as well as from the occasional benefit derived from its use in the venereal disease, it has by some writers been compared in its operation to mercury—a comparison founded on theoretical rather than practical considerations.—*Pereira*.

OIL.—*Huile*, French; *Oel*, German; *Oleum*, Latin. —Oils are a very interesting class of natural substances, inflammable, and greasy to the touch. Oily bodies are generally divided into two classes, fixed or fat oils, and essential or volatile oils. The two are, however, entirely dissimilar, both in properties and composition;

indeed, except in the one common property of greasiness, they are not at all allied to each other. The oils belonging to one classification may readily be distinguished from those of the other; the essential oils emitting at ordinary temperatures a distinctive, intensely odorous, and penetrating vapor, and when dropped on paper, not producing a permanent greasy spot, while the stain of a fixed fatty oil does not disappear by exposure, nor even when the paper is subjected to a gentle heat. For the present, to avoid confusion, only the fixed and fat oils will be considered.

Fats and fixed oils are most indispensable requisites of domestic economy, equally important as nourishment, as material for the manufacture of soap, and as sources of light. They contain a very large proportion of carbon, as compared with that of the other constituents—a character that distinguishes this class of substances from the greater number of compounds of organic origin. In many instances the amount of carbon is from seventy to eighty per cent., and upon this property depends their great value as food, and as sources of light. As regards the former, they must always be most useful; those fats only which are unfit for food are valuable as sources of light, or for the production of soap.

HISTORICAL NOTICE.—Oils have been known from the earliest ages of the world, and were, even at that remote period, applied to a variety of purposes, but principally as a means of illumination. In the writings of MOSES olive oil is frequently mentioned; and it appears probable that the candlesticks so frequently referred to in Holy Writ were intended as a support for lamps, and not candles. In Genesis MOSES speaks of a *burning lamp*, and in the two following books it is clearly stated that olive oil was the material used as the source of light. The introduction of oils into Europe dates also from a very remote age. According to HERODOTUS, the Greeks were the first European people acquainted with them. They derived their knowledge of oil, and the means of procuring it, from the Cecrops, who brought olive oil from Sais, a province of lower Egypt. No record can be found showing the method of extracting it at this early date, nor even the purposes for which it was used. The Greeks of that period appear to have been ignorant of the mode of applying it as a source of light, for HOMER mentions wood torches as a means of illumination in use at the time of the Trojan war. EUSEBIUS, however, relates that, at the commencement of the fourth century, the city of Constantinople was annually illuminated on Easter eve by means of *lamps* and wax candles. Afterwards, until the introduction of tallow and animal fats, wax and pitch were the combustible materials most commonly employed.

SOURCES.—Oils are found abundantly in the vegetal and animal kingdoms. In the former, they occur in various parts of the plant, principally in the cellular structure of, and in the fleshy pulp surrounding the seeds, and very rarely in the roots. They are contained in that part of the seed which gives birth to the cotyledons, and not in the plumula or radicle. In the olive tree only the oil is contained in the fleshy integuments of the fruit. The seeds richest

in oil are those belonging to the genus *crucifera*, and next to that are the *drupacea*, *amentacea*, and *solanca*. Linseed contains twenty per cent. of oil, rape seed from thirty-five to forty, castor seed sixty per cent., and nuts about half their weight. The quantity of oil furnished by seeds varies, not only with the species, but in the same seed, with climate and method of cultivation. The seeds should be ripe, fresh, and of good quality. The yield of oil is always less than that actually contained in the seed, and the quantity remaining in the *marc* or pressed cake is greater in proportion as the starchy, ligneous, and albuminous principles predominate. The exact quantity of oil contained in seeds is easily estimated by taking a given quantity and bruising and treating repeatedly with ether, until the oil is completely extracted. The solution is then evaporated by means of a water bath, and the oily residue remaining is washed with water, to remove soluble matters, then dried and weighed, and the result is the exact proportion of oil present in the seed.

The part of the plant in which fats and oils are originally produced, is, according to DUMAS, the green leaves only, whence they are removed by a process of circulation, and deposited in the seeds and fruits. The essential ultimate constituents of oils are carbon, hydrogen, and oxygen, and consequently they may be produced by a process of deoxidation from carbonic acid and water, which are of course imbibed for the most part by the green leaves. It is, therefore, extremely probable that the theory of DUMAS, which attributes the assimilation or process of formation of oils to the verdant foliage of the plant, is the correct one; certainly it is the only plausible one yet adduced to explain this very peculiar action. The living plant breathes, feeds, and digests, exactly as is the case with the animal, though in the plant the organs of digestion and respiration exist almost entirely in the leaves; and here the vital force, under the influence of light, effects the transmutation of the food into the several substances of which the plant is constructed, while the whole, or at least the greater portion of the oxygen of the absorbed carbonic acid, is returned by respiration to the atmosphere. The formation of vegetal oils is, therefore, owing to absorption and transformation of food containing the elements under the form of gases, which by the vital force, and the peculiar organic structure of the plant, are secreted and arranged into entirely new products.

In animals, fats are contained chiefly in the cellular membrane, and, for the most part, immediately beneath the skin; also interiorly, particularly in the omentum, and in the region of the kidneys. This substance exists in the form of globules or small drops, and swims in the animal fluid with which the cells are filled. In the species of whale, the bony cavity of the head is the depository of the secreted spermaceti, and in the case of butter, the fat is mixed in a liquid state in milk. Oils and fats, both in plants and animals, are always associated with an albuminous principle; in vegetals, with *diastase*, *synaptase*, or an analogous body, which, from its peculiar liability to change, exercises an important influence upon the oils when kept for any length of time.

Two distinct theories concerning the production of animal fats have been promulgated, and each of them has had a large number of supporters, eminent for their extensive chemical knowledge.

DUMAS is of opinion that fatty matters are not generated in the animal body, but that they are derived, already formed, solely from the vegetable kingdom, the manifold products of which serve as food for the *herbivora*, while the *carnivora* also derive them indirectly from the same source, through the plant-eating animal. This opinion has for its supporters, BOUSSINGAULT, PAYEN, and others. Undoubtedly the fat of the *herbivora* is, to a certain extent, conveyed to them in the plants which serve them as food; while, at the same time, it is indisputable that fat may also be produced by a process of deoxidation of the amylaceous constituents of food. This latter theory was advanced by LIEBIG, and is now almost universally acknowledged to be the true explanation of the formation of animal fats. A powerful argument in favor of the latter supposition is, that the *carnivora*, which, as their name implies, are flesh-eating animals, have much less fat, but more muscle, than the *herbivora*. The latter derive the substance of their bodies from plants, to the amylaceous, or saccharine, starchy, and gummy components of which are due the production of fat; the comparatively small nitrogenized portion being taken up to form muscle, and the other albuminous or nitrogenous parts of the structure. The absence of the non-nitrogenous or amylaceous ingredients in the food of animals occasions a leanness of flesh, while at the same time, it is well known that the proportion of fat in the animal body may be increased by an augmentation in the quantity of non-nitrogenous food. A curious fact in support of LIEBIG's theory was adduced by HUBER and by GUNDELACH, who fed bees *solely on pure sugar*, and found an abundant secretion of wax,—a true fat. No doubt, therefore, these insects produce wax by a process of assimilation of the sugar contained in honey: indeed, this has since been admitted by DUMAS. Animal fat may, therefore, be considered to be a product of the deoxidation of the non-nitrogenous constituents of vegetal food, and consequent upon a deficient supply of oxygen to the body, this element being absolutely indispensable to the dissipation of these components of food. It follows, therefore, that farinaceous food, and abstinence from exertion, are promotive of the formation of fat, rest being a necessary condition, as during locomotion or other exertion, respiration is more frequent, and the supply of oxygen consequently more abundant, and by its agency the formation of fat is prevented: the amylaceous constituents of the food, undergoing a species of slow combustion, are entirely broken up, and expelled from the system in the form of carbonic acid and water,—the components of the atmosphere from which they were originally produced in the plant. The above exposition is an admirable illustration of the dependence of the animal upon the vegetal kingdom, and a very important instance of the economy of nature.

PROPERTIES.—The consistence of fatty matters is very variable—from that of extreme fluidity, as in the oil of almonds, to that of solid masses, as suet or butter.

Those obtained from warm-blooded animals are usually solid at ordinary temperatures; whilst fish oils, and those procured from cold-blooded animals, remain liquid; sometimes, however, the same plant as well as animal yields both varieties. The concrete vegetal oils, as that of cocoa-nut, are sometimes designated vegetal butters.

The value of oils as combustibles is greatly affected by their degree of fluidity. This is determined by the period required for a given quantity to flow through a funnel of known dimensions. With an apparatus similar to that represented in Fig. 387, Vol. I., page 704, SCHUBLER and URE obtained the following results:—

Fluid.	Time required to flow through a given aperture. Seconds.	Fluidity. Water = 100.
Water,.....	90	100.0
Olive oil,.....	195	46.1
Colza oil,.....	162	55.5
Oil of brassica napus,.....	159	56.6
Oil of brassica præcox,.....	148	60.8
Oil of brassica napo-brass,...	142	63.3
Oil of brassica rapa,.....	136	66.1
Train oil,.....	450	20.0 Ure.

The specific gravity of oils and fats is always below that of water, and varies from 0.91 to 0.94 at 60°. The oils, of all fluids, expand the most by heat, and, indeed, in some cases to such a degree as to render it necessary, for the purposes of commerce, to know exactly the extent of this expansion. The following table, given by SAUSSURE, shows the density of several oils at different temperatures:—

	At 53°.	At 70°.	At 122°.	At 200°.
Nut oil,.....	0.928	0.919	—	0.871
Almond oil,....	0.920	—	—	0.863
Linseed oil,....	0.939	0.930	0.921	0.881
Castor oil,.....	0.970	0.957	—	0.908
Olive oil,.....	0.919	0.911	0.893	0.862

For every degree of Celsius the volume of olive oil increases, according to PREISSER, one twelve-hundredth, of rape oil one eleven hundred and twentieth, and of train oil one one-thousandth, so that one hundred measures of train oil at 32° Fahrenheit will become in summer at 68° Fahrenheit one hundred and two measures.

Common hog's lard at 60° has a specific gravity of 0.938 in its fluid state; at 122°, it is 0.892; at 155°, it is 0.881; and at 200°, 0.863. The specific gravity of oil increases also with its age; indeed, it may be remarked, that no accurate determination of the degree of purity of an oil can be deduced from its density, as there are frequent discrepancies in the same kind of oil, according to the locality where the plant was cultivated, and the varied modes of extracting the oil.

Fats and oils may be exposed to a considerably high temperature without suffering any important change; but at a heat of between 500° and 600° they are rapidly decomposed, and, therefore, will not admit of distillation. This property especially distinguishes the fixed from the essential or volatile oils, which may be distilled without alteration. The continued action of heat upon fat oils has a very remarkable effect. A little above 500° they assume a darker color, and evolve acrid and offensive vapors; and when further heated to about 600°, eliminate carbonic acid, and carbide of

hydrogen gases, accompanied by a peculiarly irritating substance termed *acrolein*, and also margaric and sebacic acids, and a variety of solid and liquid carbides of hydrogen. The result of the action of heat, however, is not always the same, but varies with the nature of the oil. The period at which these alterations occur has been improperly said to be the boiling point, the phenomena of apparent ebullition arising from the escape of the gases produced by the decomposition of the oil. When introduced in small portions into red-hot vessels, or what is the same thing, when the vapor of oils is made to pass slowly through a red-hot tube, they are almost entirely converted into volatile products, consisting principally of carbonic oxide, and gaseous, liquid, and vaporous hydrocarbons. This mixture constitutes *oil gas*, which in illuminating power is far superior to that of the best coal gas, and exceeds in this property three and a half times that of ordinary coal gas. For a detailed notice of this highly interesting and important subject—the manufacture of oil gas, and its application to lighting purposes—the reader is referred to the article *GAS*.

Olein, Stearin, Margarin, and Glycerin.—CHEVREUL, in the course of an extended examination of fixed oils, which he concluded about the year 1813, discovered them to consist of, for the most part, always two, and frequently three distinct compounds, united in the most variable proportions. These bodies are combinations of *oxide of glyceryl* with stearic, margaric, and oleic acids. For the sake of brevity, these compounds are named *stearin*, *margarin*, and *olein*, and it is upon the prevalence of one or other of these ingredients that the consistence of fat depends. When stearin predominates, the fat is firm and solid; if margarin be most abundant, the fat is less hard; while if olein is the chief principle, the oil is liquid at ordinary temperatures.

BRACONNOT, who investigated this subject about the same period, gives the following table of the results of his experiments, showing the centesimal proportion of solid matter contained in the oils and fatty bodies therein mentioned:—

	Solid matter in one hundred parts.	Degrees
Cow's butter in summer, . . .	40	fusible at 134.5
Cow's butter in winter,	65	— 134.5
Lard,	30	— 110.0
Ox fat,	76	— 141.0
Mutton suet,	26	— 123.8
Goose's fat,	32	— 111.2
Duck's fat,	28	— 125.5
Fat of turkeys,	26	— 113.0
Olive oil,	28	— 68.0
Oil of almonds,	24	— 42.8
Colza oil,	46	— 45.5

Fats, therefore, as taken from vegetal or animal bodies, are not homogeneous chemical combinations, but mixtures of such, which, taken singly, have all the properties of the fats themselves. By congelation at low temperatures, and pressure of the concrete mass, a separation of the oil ensues into a liquid and a solid portion. The former consists of olein, and the latter of stearin or margarin, or both. By pressure between folds of blotting paper, or in linen bags, a nearly complete separation of the olein is effected, and the solid stearin

or margarin remains. By heating the paper in water, the liquid olein may be obtained separate. Tolerably pure stearin may also be procured by boiling the natural oil with alcohol, in which stearin is nearly insoluble. Besides the above process for procuring olein by refrigeration, it may be obtained by boiling oil for some time with a small proportion of caustic soda or potassa, and treating the mixture with dilute alcohol, when the olein collects as an oily layer upon the surface of the liquid. For the preparation of olein, almond oil should be employed, as it contains a greater quantity of this principle than other oils. Stearin constitutes by far the greatest proportion of the solid components of fats and fixed oils. The properties of these ingredients vary with the nature of the respective oils, so that the sole difference does not consist in the variable proportions of the three bodies, but also in peculiarities of the principles themselves; as it has been found that, according to their source, they solidify at very different temperatures.

When oily seeds, such as almonds, walnuts, or poppy seeds, are crushed or pulverized, so as to break up the cellular tissue, and bring its various ingredients into intimate admixture with each other, the fatty bodies, which the seeds naturally contain as neutral compounds, are gradually resolved into fatty acids, with simultaneous liberation of a colorless, inodorous, and sirupy liquid. The latter is *glycerin*, and was called by SCHEELE, its discoverer, the sweet principle of oils. The change is owing to the presence of a peculiar albuminous body, previously mentioned as being always associated with oils. This nitrogenous matter, gradually decomposing, acts as a ferment, and produces the above alteration in the constitution of the oils, and, as PELOUZE has shown, is independent of any absorption of oxygen. When heated with the hydrates of the fixed alkalies, with the alkaline earths and other metallic oxides, in presence of water, decomposition also ensues, the oily acids combine with the alkali or metallic oxide used, yielding oleates, margarates, and stearates; the oxide of glyceryl with which these acids were united separating in chemical combination with a certain proportion of water, the product being glycerin. This peculiar principle—the base of oils—in consequence of its growing importance in the arts and manufactures, and particularly as an article of the *materia medica*, has been made the subject of a separate article, to which the reader is referred. The three substances constituting the proximate principles of fats and oils, have also been noticed under the article *CANDLE*, where full information as to the mode of preparation, properties, and uses, will be found, together with a description of the respective acids entering into their constitution. It may be mentioned, that although the three components of oils—olein, stearin, and margarin—are respectively compounds of oleic, stearic, and margaric acids with the basis of glycerin, simple mixture of the fatty acids with the glycerin does not reproduce the oil from which they were obtained, in consequence of the metallic base, in displacing the oxide of glyceryl, having given up a portion of its water to it, while the fatty acids, in the process of separation from the metallic oxide, have also

united with a portion of water. In fact, the united weight of the fatty acids and glycerin always exceeds by three or four per cent. that of the oil originally employed. The water absorbed so modifies the constitution of the acid and base as to prevent the re-formation of the fatty bodies, of which they are the essential constituents.

BERTHOLLET has, however, recently succeeded in reproducing the natural fats by a direct union of their acids with the base of glycerin. According to this chemist, stearic, margaric, and oleic acids, each form three compounds, by uniting with oxide of glyceryl; during combination, water is separated in each case, but there appears to be a doubt as to the accuracy of his determinations of the precise quantity of water liberated. BERTHOLLET's researches on this subject have been noticed at some length in the article on GLYCERIN.

Other Constituents.—In addition to the three neutral principles, stearin, olein, and margarin, of which at least two are always contained in oil, many oils and fatty bodies contain another or more substances analogous in composition to these bodies, but essentially different in their properties. Some, like those above named, are, by the action of suitable reagents—for example, when treated with hydrates of the fixed alkalies—resolved into a fixed fatty acid and glycerin; others, when similarly treated, yield glycerin and a volatile fatty acid, and it is to the presence of the latter that the peculiar and characteristic flavor and smell of the various fatty bodies are to be attributed. In the appended table are given the names of these peculiar principles, with the acids yielded by each, and, so far as they are known, the melting points of the fat and of the acid:—

FATS YIELDING FIXED ACIDS.

Melts at		Melts at
Laurostearin, .. 113°	Laurostearic acid, $C_{24}H_{48}O_4$	—109°·4
Cocosin, 716	Cocinic acid, $C_{23}H_{46}O_4$	— 95
Myristin, 87·8	Myristic acid, $C_{25}H_{48}O_4$	—120·2
Benin, —	Benic acid, $C_{30}H_{60}O_4$	—109·4
Moringin, —	Moringic acid, $C_{30}H_{58}O_4$	— 32
Linolein, —	Linoleic acid, $C_{30}H_{54}O_4$	—
Palmitin, 118·4	Palmitic acid, $C_{32}H_{64}O_4$	—140
Butyrolein, —	Butyroleic acid, .. —	—
Ricinolein, —	Ricinoleic acid, ... —	—
Elaidin, 96·8	Elaidic acid, $C_{36}H_{72}O_4$	—111·2
Margaritin, —	Margaritic acid, .. $C_{22}H_{44}O_4$	—185

FATS YIELDING VOLATILE ACIDS.

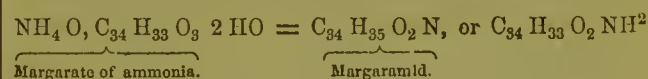
Butyrin,	Butyric acid,	C_8	H_8	O_4
Valerin, or Delphinin,	Valerianic acid,	C_{10}	H_{10}	O_4
Caproin,	Caproic acid,	C_{12}	H_{12}	O
Caprylin,	Caprylic acid,	C_{18}	H_{16}	O_4
Caprin,	Capric acid,	C_{20}	H_{20}	O_4
Hircin,	Hircic acid,	—	—	—
Sabadillin,	Sabadillic acid,	—	—	—
Crotonin,	Crotonic acid,	—	—	—
Ricinin,	Ricinic acid,	C_{22}	H_{19}	O_4-70°

Of the above principles, many are unknown in the separate state, and are supposed to exist merely from the liberation of their fatty acids by the saponification of the natural fats, and subsequent treatment with acid.

Action of Alkalies on Oils—Soaps—Margaramid.—The combination of the fatty acids with alkaline and other bases gives rise to the production of soap, which

will be discussed in a separate article. It may suffice here to observe, that the compounds of the fatty acids with the fixed alkalies constitute soluble soaps; and, with the earthy and metallic bases, insoluble soaps. In the cases of oxide of lead and of zinc, they are termed *plasters*.

The action of ammonia upon the fixed oils differs from that of the other alkalies and metallic bases. If the emulsion obtained by agitating solution of ammonia with a fatty oil be, soon after being prepared, mixed with sufficient dilute acid to neutralize the ammonia, or if the mixture of oil with ammonia be exposed to the air, the volatile alkali after some time is completely dissipated, and the oil is reproduced in its original state. As already observed, simple admixture of glycerin with the fatty acids does not reproduce the oil yielding them; and, therefore, the reproduction of the oil unaltered, after expulsion of ammonia, is a proof that no combination of ammonia with the fatty acids had been formed. Prolonged contact of ammonia with oils in a closed vessel, however, gives rise to the formation of true salts of ammonia with the fatty acids, or ammoniacal soaps; but in addition to these, there is produced also a peculiar substance to which its discoverer, BOULLAY, has given the name of *margaramid*. It is an amide of the fatty acid, and may be obtained by treating the soap of ammonia with boiling water, by which means it is thinned out, but not dissolved, and on cooling, the greater portion coagulates at the surface. The coagulated mass is dissolved in boiling alcohol, and on cooling, margaramid is thrown down as a white, crystalline, perfectly neutral substance. The composition of margaramid is margarate of ammonia, minus two equivalents of water:—



Margaramid is unalterable in the air, insoluble in water, but readily dissolved by alcohol or ether. It fuses at 140°, burns with a sooty flame, is decomposed by boiling concentrated solutions of the fixed alkalies, and also by acids when at a certain degree of concentration. The transformation of oils into margaramid by the action of ammonia is especially rapid and characteristic in the case of castor oil.

Action of Acids on Oils—Sulphuric Acid.—The action of acids upon oils has been the subject of many recent critical examinations. The changes produced vary with the kind of acid employed. Sulphuric acid, when added to many oils to the amount of one per cent., has no action upon the oil itself, but it instantly develops a dark green or brownish coloration. After some time, a chemical combination of the acid with mucilage and other parenchymatous matter is deposited, and the oil is thus rendered brighter and more limpid. When sulphuric acid is added in larger quantities, very remarkable changes occur. In moderate proportion, its action appears to be limited to the abstraction of the oxide of glyceryl, with which it combines and forms bisulphate of oxide of glyceryl, or sulphoglyceric acid— $C_8H_7O_5 \cdot 2SO_3$, whilst the oily acids are set at liberty. When applied in larger quantities,

the result is the conversion of the fatty acids into various modifications, sulpho-glyceric acid being a simultaneous product. If sulphuric acid be gradually added in the cold to twice its volume of olive oil, the mixture becomes tough in appearance, and if, after standing twenty-four hours, two volumes of water be added, sulpholeic, sulpho-margaric, and sulpho-stearic acids separate and rise to the surface; for, though soluble in pure water, these acids are quite insoluble in the acid liquid. When the solution of these acids in water is kept for some time at ordinary temperatures, the sulphuric acid separates, and there are produced three new acids—metamargaric, metoleic, and hydromargaric acids. The two former rise to the surface, and the latter remains dissolved in the water along with sulphuric acid. On heating the original solution, there is formed a fourth, hydroleic acid, which rises to the surface in admixture with the acids above mentioned; and if this mixture is boiled with alcohol, still another acid is produced—the hydromargaritic, which is deposited from the solution on cooling. FREMY was the first to notice these peculiar reactions; the subject has, however, since been investigated by others, and especially by MILLER and VARRENTRAPP, but is still to a great extent involved in mystery. The sulpho-acids have an oily, bitter taste. Of the three, sulpholeic is by far the most permanent.

The action of sulphuric acid upon oils or fats at a high temperature, differs from the above; a separation of the fatty acids and oxide of glyceryl is immediately effected, and the glycerin and sulphuric acid mutually decompose, yielding sulphurous and carbonic acids. The application of this reaction to the separation of the fatty acids, for manufacturing purposes, has already been discussed in connection with the article CANDLE.

Action of Nitrous Acid—Elaidin.—The action of nitrous acid upon fixed oils varies with the kind on which it operates. According to their behavior under the influence of this acid, they are divided into two distinct classes or divisions—the *drying* and the *non-drying* oils. The latter by this treatment are converted into solid masses, a change of which those of the first division are not susceptible. The reaction appears to be confined to one of the principles of the greasy oils—olein; and its effect is to convert this, the most liquid of the components of oil, into a concrete fatty matter, termed *elaidin*, which by analysis is found to consist of a peculiar acid—elaidic acid—in combination with oxide of glyceryl. This action was first observed by POUTER, a French apothecary, in the course of experiments on olive and other oils. BOUDET showed nitrous acid to be the true agent of decomposition. According to the quantity employed, the change is effected in a longer or shorter period of time. Thus, a mixture of three parts of nitric acid, with one of nitrous acid, gave the following results:—

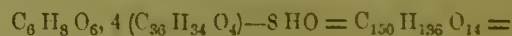
1 part of the acid with 33 of olive oil solidified in 70 minutes.		
1	50	78
1	75	84
1	100	130
1	200	435
1	400	remained unchanged.

The annexed table indicates the time required, at

the temperature of 60°, for the congelation of one hundred grains of oil, when treated with three grains of nitric acid, and three of pure nitrous acid:—

	Color immediately developed	Number of minutes before congelation.
Olive oil,	Bluish green,	73
Sweet almond oil, ..	Dirty white,	160
Bitter almond oil, ..	Deep green,	160
Nut oil,	Bluish green,	163
Castor oil,	Bright yellow,	603
Colza oil,	Brown yellow,	2400

The very small quantity required to produce the effect, and the remarkable fact, that in some cases a similar solidification is produced by a deoxidizing agent—sulphurous acid—render this action a problem as yet unexplained. Protonitrate of mercury also induces a similar change on the greasy oils, and in all cases, with the exception of castor oil, the product of the action is the same. Pure elaidin is best obtained by agitating olive oil with a mixture of nitrous and nitric acid. To procure this mixed acid, one part of nitrate of lead is heated in a retort connected with a receiver, in which is contained one part of nitric acid, of specific gravity 1.35. To one hundred parts of olive oil are added ten parts of this mixture of acids, and the whole is agitated till it begins to solidify. It is then allowed to stand at rest, and gradually a yellowish semi-solid mass is formed. This, when washed with alcohol, becomes white, and after pressing strongly between folds of bibulous paper, and subsequent crystallization from ether, yields pure elaidin. As thus procured, elaidin is solid at ordinary temperatures, and when heated with alkalis or metallic oxides, is saponified. It fuses at a temperature between 90° and 100°, is almost insoluble in alcohol, but is readily dissolved by ether, and in all proportions. Its specific gravity is 0.8978, and by distillation it yields, among other products, acrolein, and elaidic and sebacic acids. The stearin and margaric of fats are not transformed into elaidin, though this change is stated to occur by some chemists. According to GOTTLIEB, the production of elaidin is due solely to the conversion of oleic acid into an isomeric modification, but how the acids effect the transformation is still a matter for further research. A small quantity of ammonia is formed during the reaction—a proof of the decomposition of a portion of the acid. The drying oils, as those of linseed, poppy seed, and hemp, undergo no metamorphosis by the action of nitrous acid, except that they are slightly tinged brown. The composition of elaidin is exactly the same as the olein from which it is produced— $C_{150}H_{136}O_{14}$ —and consists of one equivalent of glycerin, and four of elaidic acid, minus eight equivalents of water—



one equivalent of elaidin.

Elaidic acid is prepared by saponifying elaidin, by heating it with a fourth of its weight of caustic soda or potassa, and half its weight of water. The resulting soap is a mixture of margarate and elaidate of potassa or soda, and when treated with hydrochloric acid, chloride of the metal of the alkali is formed, and a mixture of elaidic and margaric acids liberated. According to MEYER, it may be obtained pure by passing

a current of nitrous acid, as disengaged by the deoxidation of nitric acid when heated in contact with starch, through pure oleic acid at a low temperature, and avoiding the use of an excess of acid. The liquid after a short time congeals into a crystalline mass. This is washed with hot water to remove nitric acid, and then dissolved in its own volume of hot alcohol. On cooling, elaidic acid is deposited as a mass of crystalline scales, which may be purified by pressure, re-solution, and recrystallization, from alcohol.

MORFIT gives a method for preparing this acid on the large scale. Oleic acid is to be treated with steam at a high temperature, and afterwards there is added exactly sufficient solution of carbonate of potassa to neutralize any sulphuric acid it may contain. After standing some time, the oil rises to the surface of the condensed steam, and must be siphoned off into a wooden tub. To every two thousand pounds is then added an intimate mixture of eighty-one pounds of nitric acid, of specific gravity 1.35, and thirteen and a half pounds of molasses, and the whole is very gently heated by steam passed in through a worm of copper, having its terminus above the kettle, as it is not desirable that any water should get into the oily matter at this stage of the operation. When red fumes begin to appear, the action must be checked by drenching with four or five hundred gallons of water, after which an aqueous solution containing forty to fifty pounds of acetate of ammonia is added. During all these operations, the mass should be constantly agitated, and, after the addition of water, very briskly for two or three hours. The water and agitation withdraw all acid matters, and leave the elaidic acid in a condition to be drawn off, after repose, into small tubs, and cooled. Neutral oils by the same treatment yield elaidin, and this latter, as well as elaidic acid, is an excellent material for the manufacture of soap and candles. Elaidic acid is a pearly crystalline solid, resembling in appearance the silvery scales of sublimed benzoic acid. It fuses at about 112° , is readily soluble in alcohol, less so in ether, and quite insoluble in water. When distilled, a great portion passes over unaltered, the remainder is decomposed into carbides of hydrogen, but no sebacic acid.

As already observed, GOTTLIEB has shown that elaidic acid is isomeric with oleic acid. Its composition is, therefore, $C_{36}H_{33}O_3$, $HO = C_{36}H_{34}O_4$. This chemist proved likewise, that a small quantity of freshly-prepared claidic acid, when mixed with a large proportion of oleic acid, gradually converts the whole mass into elaidic acid; and also that when exposed to the air, elaidic acid gradually becomes oxidised to oxyelaidic acid $= C_{36}H_{34}O_6$, whilst oleic acid submitted to the same influence, gradually passes into $C_{36}H_{34}O_6$.

Action of Chlorine, Bromine, et cetera.—The fixed oils are decomposed by chlorine and bromine, yielding hydrochloric and hydrobromic acids. Compounds of the oil are also at the same time formed with those radicals, in which it frequently happens, that each equivalent of hydrogen abstracted is replaced by one of the halogen. Iodine is generally dissolved, forming a brown solution. Sulphur is also soluble in oils, and, if heated, rather largely; the greater portion, however, is deposited on cooling; but if the tempera-

ture of the mixture be increased to the point at which the oil begins to be decomposed, sulphide of hydrogen is evolved, and a permanent solution formed. This compound is not saponifiable, it mixes with the fat and volatile oils, and, when long exposed to the air, dries into an elastic substance, insoluble in ether. When distilled, among other products sulphide of hydrogen is evolved, and a black porous mass remains, containing centesimally forty-five of sulphur, and fifty-five of carbon, and is expressed by the formula— SC_3 . Phosphorus and selenium are also sparingly soluble in the fixed oils.

The action of steam at a high temperature upon fatty oils was investigated by TILGHMAN. He observed that when a mixture of fat and water is forced, under strong pressure, through tubes heated nearly to redness, so as to raise the temperature of the mixture to between 400° and 500° , the fatty matter is entirely decomposed into glycerin and fatty acids; the elements of water enter into combination with those of the fat, and by this means a result is obtained exactly the reverse of that produced by BERTHOLLET at lower temperatures, when the acid and base are caused to reunite, again producing the natural fat. The application of TILGHMAN'S discovery to the preparation of the pure fatty acids, has been treated of at length in connection with the article CANDLE.

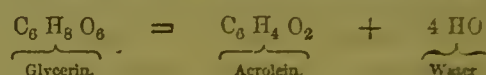
Sebacic Acid.—It has already been observed that the fixed oils, when submitted to distillation *per se*, are decomposed, yielding, besides carbonic acid, inflammable gas, and various hydrocarbons—*margaric* and *sebacic* acids, and a substance termed *aerolein*. A portion of oleic acid also passes over unchanged. Sebacic acid, with the exception of castor oil, is yielded by all oils, whether animal or vegetable, drying or non-drying oils. It is formed exclusively from the decomposition of oleic acid. Stearic and margaric acids, as well as pure margarin and stearin, do not yield a trace of it. The detection of sebacic acid amongst the products of this decomposition is, therefore, a certain test of the presence of an oil, and especially of olein or oleic acid. As produced from oleic acid, it is accompanied by a considerable quantity of capric and caprylic acids, with traces of valerianic and butyric acids. To obtain it pure, the whole liquid and solid products of the distillation of oils or fats, or better, of pure olein or oleic acid, are boiled with water, until the soluble portion is extracted. The aqueous liquid deposits sebacic acid on cooling. The crystals are purified by washing with cold water, and recrystallizing from the hot solution, till they become colorless, and free from empyreumatic smell. Or the watery solution is precipitated by adding acetate of lead, which throws down sebate of lead. This, after washing, is dried; and, decomposed by dilute sulphuric acid, yields a solution which, on evaporation, deposits pure crystals of sebacic acid. According to DUMAS and PELIGOT, its ultimate composition is as annexed:—

	At weight.	Centesimally.
10 Eqs. of carbon,.....	60	59.4
9 Eqs. of hydrogen,.....	9	8.9
4 Eqs. of oxygen,.....	32	31.7
1 Eq. of sebacic acid,.....	101	100.0

As thus obtained, the acid is combined with one equivalent of water, and is, therefore, expressed by the formula, $C_{10}H_8O_3, H_2O$. Hydrated sebacic acid forms light, white, pearly scales, resembling benzoic acid in appearance; indeed, it was considered by BERZELIUS to be identical with this acid. It has a very slightly acid taste, but reddens litmus. It fuses at 260° to an oily liquid, and, at a higher temperature, sublimes unchanged. It is much more soluble in hot than in cold water, and is readily dissolved by alcohol or ether. With the alkalis it forms soluble sebates, but its salts, with other metallic oxides, are for the most part insoluble. LIEBIG and REDTENBACHER were the first to notice this acid as a certain and delicate test of the presence of oleic acid.

Acrolein.—Acrolein is another highly characteristic product of the decomposition of oils by the application of a high temperature. When the volatile products arising from the destructive distillation of oils or fats, are passed through a series of bottles, half filled with water, the second and third bottles retain the greater portion of the acrolein, partly in solution in the water, and partly in the form of an oil floating on the surface of the liquid. When this floating oil is agitated with twenty times its bulk of water, the greater part of it is dissolved; and when this solution is distilled in a water bath, an oily matter—nearly pure acrolein—passes over at about 125° . According to REDTENBACHER, it is most readily obtained in a state of purity by distilling, in a capacious retort, a mixture of glycerin with anhydrous phosphoric acid, or bisulphate of potassa; the vapors are condensed in a receiver placed in a freezing mixture. The receiver is luted on to the retort, and is provided with a tube conducting into a chimney with a good draught, so as to carry off any uncondensed acrolein. To exclude atmospheric air, the oxygen of which rapidly combines with acrolein, the whole apparatus must be charged with carbonic acid, and the current be continued to the end of the process. The distillate separates into two layers, of which the upper one consists of acrolein, and the lower one of an aqueous solution of the same substance, and containing also another body resulting from the oxidation of acrolein. The latter is acrylic acid, very analogous to acetic acid, and is produced during the distillation, even in the presence of carbonic acid. The distillate, with the addition of a quantity of powdered litharge, to retain acrylic acid, is rectified by the heat of a water bath, and the acrolein thus obtained is submitted to another rectification from chloride of calcium, and is then as pure as it has yet been obtained. Acrolein is especially remarkable for the peculiarly pungent and acid nature of its vapor, intensely disagreeable and irritating to the eyes and nose, the evaporation of even a few drops, in a large room, causing a copious flow of tears in the eyes of all present, and with severe pain. It is a colorless, limpid, and volatile oily liquid, possessing a high refracting power, is very soluble in ether, and sparingly so in water. It boils at 125° . It is assumed to be the hydrated oxide of a radical termed, *acryl*— C_3H_3 , and its formula is C_3H_3O, H_2O . When long kept, it changes spontaneously into a white, flocculent, inodorous substance,

which REDTENBACHER named *disacryl*. The latter body is insoluble in ether, oils, acids, and alkalis. As it is formed even when acrolein is excluded from air, it is in all probability an isomeric modification of this body. The aqueous solution of acrolein also gradually undergoes a similar change. Sometimes acrolein, under the same circumstances, becomes transformed into a resinoid mass, which fuses at 212° , and forms a brittle transparent mass, on cooling. This substance is insoluble in water, but soluble in alcohol and in solutions of the alkalis. Acrolein owes its formation solely to the decomposition of glycerin, and its production is, therefore, an extremely sensitive test of the presence of the latter body. It appears to be produced by a dehydration of glycerin, since this substance contains the elements of acrolein, *plus* four equivalents of water.



Acrolein and its products of oxidation are remarkably analogous to aldehyde and its products, as will be observed by a comparison of the subjoined tables:—

Acryl,.....	C_3H_3 —unknown.
Hydrated oxide of acryl—acrolein—	C_3H_3O, H_2O .
Acrylous acid,.....	$C_3H_3O_2, HO$.
Acrylic acid,.....	$C_3H_3O_3, HO$.
Acetyl,.....	C_2H_3 —unknown.
Hydrated oxide of acetyl—aldehyd—	C_2H_3O, HO .
Acetous acid,.....	$C_2H_3O_2, HO$.
Acetic acid,.....	$C_2H_3O_3, HO$.

It may be observed that STENHOUSE found in palm oil, and PLAYFAIR in butter of nutmegs, a base having the same formula as acrolein— $C_3H_4O_2$. This substance, however, when separated from the oily acid, always appears as ordinary glycerin.

Elementary Composition of Oils.—From what has been detailed as to the proximate constituents of oils, it will hardly be thought necessary to notice their elementary composition. Indeed, a knowledge of the ultimate analysis of any organic body, is only a very slight assistance to the chemist in the determination of the true composition of these substances. This can only be arrived at, to any degree of certainty, by a thorough investigation of the changes induced by the action of reagents, and an accurate determination of the quantities of the several products, as well as their composition. It is owing to the application of this principle, first laid down by the illustrious CHEVREUL, that, in the hands of such philosophers as LIEBIG, DUMAS, BOUSSINGAULT, BUNSEN, WÖHLER, and others, organic chemistry has made such rapid strides during the last half century. The Editor has, however, annexed a table, showing the relative centesimal proportions of carbon, hydrogen, and oxygen, in each of the following oils, together with the name of the authority:

	Carbon.	Hydrogen.	Oxygen.	Authority.
Olive oil,.....	77.21 ..	13.36 ..	9.43 ..	{ Gay-Lussac and Thenard.
Almond oil,.....	77.40 ..	11.48 ..	10.82 ..	Saussure.
Linseed oil,.....	76.01 ..	11.35 ..	12.62 ..	Do.
Nut oil,.....	79.77 ..	10.57 ..	9.12 ..	Do.
Castor oil,.....	74.17 ..	11.03 ..	14.78 ..	Do.
Whale oil,.....	76.13 ..	12.40 ..	11.50 ..	Bérard.
Spermaceti oil,...	78.91 ..	10.97 ..	10.12 ..	Ure.
Hog's lard,.....	79.09 ..	11.14 ..	9.75 ..	Chevrenl.
Suet,.....	78.99 ..	11.70 ..	9.30 ..	Do.
Butter,.....	65.60 ..	17.60 ..	16.80 ..	Bérard.

All fixed oils consist essentially of these three elements only, some, however, yield minute traces of nitrogen, referable to adhering impurities.

Drying and Non-Drying Oils.—Excluded from air, oils may be preserved unchanged for a lengthened period; but when exposed to the air, some oils, through the absorption of oxygen, become converted into a thick and viscid mass; others are changed into a transparent resinous body or varnish, especially when they are in thin strata. This reaction constitutes another well-marked distinction of the oils into the two classes, *non-drying* or *greasy* oils, and *siccative* or *drying*. The former class, though they may acquire more color and solidity, never lose their property of communicating a greasy stain, and the latter, as already mentioned, do not solidify when mixed with nitrous acid, or protonitrate of mercury. Oleic acid, as obtained from drying oils by absorption of oxygen, dries to a resinous mass, like the oil from which it is derived, and appears to be a distinct substance from the oleic acid of non-drying or greasy oils. The most important drying oils are those of linseed, poppy seed, grape seed, and nuts; and all are much more susceptible of the change after having been heated with the addition of a small quantity of oxide of lead. The principal non-drying oils are those of olive, colza, sweet almonds, rape seed, and palm oil. These, under the same circumstances, acquire rancidity, become thick and less combustible, and assume an offensive smell, more especially when they contain much impurity, such as albumen or mucilage.

SAUSSURE has particularly investigated this action of air or oxygen on oils, and has announced the phenomena occurring during exposure as follows:—He found that the recently-expressed fixed oils are scarcely affected by the oxygen of the atmosphere, but that after a variable period, sometimes of several months, but dependent upon temperature and exposure to light, they begin rapidly to absorb oxygen, and evolve hydrogen and carbonic acid gases. SAUSSURE's experiment to prove the absorption of oxygen by oil was the following:—A layer of nut oil, one quarter of an

inch thick, and three inches in diameter, was inclosed in oxygen gas standing over quicksilver. During eight months, from December to August, the oil absorbed only three times its bulk of gas, but in the course of ten days in the latter month, it absorbed sixty additional volumes. This absorption of oxygen diminished progressively, and at the end of three months, entirely ceased, and the oil had taken up one hundred and fifty-five times its bulk of the gas. No water was generated, but twenty-two volumes of carbonic acid were disengaged, and the result was a transparent jelly, which did not produce a stain on paper. Linseed oil, in undergoing this metamorphosis, does not evolve any gas. Under certain circumstances, the alteration by the action of oxygen may become so energetic as to lead to a considerable elevation of temperature, and ultimate inflammation, and particularly if the surface of the oil is greatly extended, as in the case of oily wool or hemp, or greasy cloth, which, when left in a heap, has frequently taken fire spontaneously, and caused the destruction of mills, warehouses, and ships; indeed, so frequently has spontaneous combustion arisen from this circumstance, causing lately the almost total destruction of one of the noblest of British merchantmen, as to render precaution necessary in all cases where danger can arise from such causes. In illustration of these occurrences, it may be proved experimentally that if paper, linen, tow, wool, cotton, or bodies of a like nature, be slightly imbued with linseed or hempseed oil, and placed in contact with sun and air, especially when in heaps or piles, they will quickly inflame. This spontaneous combustion is owing to rapid absorption of oxygen by the oil, the hydrogen of which is inflamed by the caloric eliminated from the gas at the moment of its absorption, until then existing as latent heat, and serving to retain the oxygen in its gaseous condition.

Enumeration of Vegetal Greasy Oils.—The subjoined is a list of the principal greasy oils of commerce, with the plants that yield them, their specific gravity, and the per centage amount of oil that may be extracted from some of the seeds mentioned:—

	Plants.	Specific gravity.	Yield of oil per cent. From olives.
Olive oil,.....	Olea Europea,.....	0·9176	32
			From seeds.
Rape seed oil,.....	Brassica campestris et napus,.....	0·9136	30 to 36
Colza oil,.....	Brassica campestris oleifera,.....	0·9136	36 to 40
Summer rape seed oil,.....	Brassica præcox,.....	0·9390	36 to 40
Almond oil,.....	Amygdalus communis,.....	0·9180	28 to 54
Cocoa-nut oil,.....	Cocos nucifera,.....	—	—
Palm oil,.....	Cocos butyracea vel avoira elais,.....	0·9680	—
Teel oil,.....	Sesamum orientale,.....	—	40
Oil of behen or ben,.....	Guilandina mohringa,.....	—	—
Beech oil,.....	Fagus silvatica,.....	0·9225	15 to 17
Oil of mustard,.....	Sinapis nigra et arvensis,.....	0·9160	15 to 38
Plum kernel oil,.....	Prunus domestica,.....	0·9127	33·3
Butter of cacao,.....	Theobroma cacao,.....	0·8920	—
Laurel oil,.....	Laurus nobilis,.....	—	—
Ground nut oil,.....	Arachis hypogæa,.....	0·9242	60
Piney tallow,.....	Vateria Indica,.....	0·9260	—
Oil of radish seed,.....	Raphanus sativus oleifera,.....	0·9187	50
Cherry-stone oil,.....	Prunus cerasus,.....	0·9239	—
Apple seed oil,.....	Pyrus malus,.....	—	—
Spindle-tree oil,.....	Euonymus Europeus,.....	0·9380	—
Cornel-berry-tree oil,.....	Cornus sanguinea,.....	—	—
Oil of the roots of cyper grass,.....	Cyperus esculenta,.....	0·9180	—
Henbane seed oil,.....	Hyoscyamus niger,.....	0·9130	—
Horse-chestnut oil,.....	Æsculus hippocastamus,.....	0·9270	2 to 8

Characters of the Drying Oils.—The drying oils vary from those just enumerated, by becoming gradually converted into solid masses by exposure to the atmosphere, and also by not being solidified by contact with nitrous acid or protonitrate of mercury. Their principal use is in the preparation of varnishes and painters' colors, and the more quickly they become hard by exposure, the more valuable are they for these purposes. Their siccatve properties may be much increased by heating them with about seven or eight per cent. of their weight of litharge, which, in this proportion, is, for the most part, dissolved by the oil. The heat is continued until the oil acquires a reddish hue. Oxide of manganese, oxide and sulphate of zinc, and magnesia, have also been used to produce a similar effect; what is technically known as *boiled oil*, being linseed oil which has been thus treated. According to CHEVREUL, the common practice of heating the oil to a very high degree, and for a considerable length of time, is not essential to the production of a good drying oil; linseed oil heated to 140°, with the addition of ten per cent. of its weight of oxide of manganese, having acquired powerful siccatve properties. LIEBIG is of opinion that the increased rapidity with which oils thus treated become hard on exposure, is owing to the separation of the mucilaginous and other matters, by the oxide of lead, and that the atmospheric oxygen is thus brought more closely into contact with each particle of oil. DUMAS and others consider the effect to be due, in a great measure, to the presence of oleate and stearate of lead dissolved in the oil. Another view, which the Editor, however, considers fallacious, supposes the conversion of the oil into varnish to be the result of the saponification of the fatty acid by means of oxide of lead, and the simultaneous destruction of the oxide of glyceryl by the agency of heat. But if linseed oil be saponified in the ordinary manner, and the soap produced be afterwards decomposed by means of an acid, so as to separate the whole of the glycerin, and as much oxide of lead be then dissolved in the fatty acid as will allow the mass to remain fluid on cooling, no varnish is obtained, and this is positive proof that the destruction of the oxide of glyceryl is not the object of the manufacture of quick drying oils. If a previous remark be borne in mind, that the drying oils, as shown in the experiments of SAUSSURE, absorb oxygen from the air with much greater rapidity at a later period, than when first exposed, it will appear probable that one or other of the foreign matters present retard the absorption, and this being dissipated after a

long resistance, the oil is brought more freely into contact with oxygen. The formation of varnish is thus reduced to a simple purification of the oil, by removing all those substances which prevent the immediate contact of the oil with atmospheric oxygen. Adopting this highly probable assumption, LIEBIG devised a method for removing the mucilaginous impurities by precipitation at the ordinary temperature. He recommends for the production of a superior and less colored drying oil, that the oil be agitated for some time with a mixture of water, litharge, and subacetate of lead, without the application of heat. In prosecuting this method, the basic acetate of lead is first prepared as follows:—One part of neutral acetate of lead is dissolved in five parts of water, and to the solution is added one part of finely reduced litharge. The whole is allowed to digest until the red of the litharge has been replaced by a white color. The clear solution of basic acetate is then decanted, and mixed with an equal quantity of water, and added to twenty parts of linseed oil, which has previously been triturated with one part of finely powdered litharge. The mixture now requires to be shaken at intervals, and subsequently allowed to remain at rest for some hours, when the impurities subside with the water, and the supernatant oil is so pure that it dries into a varnish in twenty-four hours. In this case, a small quantity—four to five per cent.—of oxide of lead is retained in solution by the oil; but contrary to its effect, after being boiled with the oil, it improves, rather than deteriorates, the varnish produced. Should it, however, in any way interfere with the uses to which the oil is to be applied, it may easily be removed by agitation with dilute sulphuric acid. The solution of acetate of lead employed in the above method of purification, and which collects below the stratum of oil, may be again used in the preparation of the subacetate, by the addition of litharge as before.

The oil or varnish taken for the preparation of printers' ink, is procured by boiling drying oils in an earthenware vessel. After ebullition for a sufficient length of time, the vessel is removed from the fire, and uncovered, when the vapors inflame. It is allowed to burn for about half an hour, then extinguished by replacing the cover, and again seethed until it acquires the proper consistence, and the tendency to dry quickly.

Enumeration of Drying Oils.—The following is a list of the principal drying oils, with their sources, specific gravity, and the per-centage yield of some of the seeds:—

	Plants.	Specific gravity.	Centesimal yield
Linseed oil,	<i>Linum usitatissimum</i> et perenne,	0.9347	11 to 22
Nut oil,	<i>Corylus avellana</i> et <i>juglans regia</i> ,	0.9260	60
Poppy oil,	<i>Papaver somniferum</i> ,	0.9243	56 to 63
Hempseed oil,	<i>Cannabis sativa</i> ,	0.9276	14 to 25
Castor oil,	<i>Ricinus communis</i> ,	0.9611	25
Grape seed oil,	<i>Vitis vinifera</i> ,	0.9202	—
Cucumber oil,	<i>Cucurbita pepo</i> et <i>melapepo</i> ,	0.9231	—
Sunflower oil,	<i>Helianthus annuus</i> et <i>perennis</i> ,	0.9262	15
Tobacco seed oil,	<i>Nicotiana tabacum</i> et <i>rustica</i> ,	0.9232	—
Oil of julienne,	<i>Hesperis matronalis</i> ,	0.9281	18
Oil of camellina,	<i>Myagrum sativa</i> ,	0.9252	28
Oil of weld seed,	<i>Reseda luteola</i> ,	0.9358	—
Oil of cress seed,	<i>Lepidium sativum</i> ,	0.9240	56 to 58
Oil of deadly nightshade,	<i>Atropa belladonna</i> ,	0.950	—
Oil of cotton seed,	<i>Gossypium barbadense</i> ,	—	—
Pinetop oil,	<i>Pinus abies</i> ,	0.9285	—

Extraction of Oils from Seeds.—The vegetal oils are for the most part obtained by expression, the seeds being previously ground or bruised. Some seeds after this treatment readily yield to pressure, and give what is known as virgin oil, possessing an agreeable taste; others, especially those containing a large proportion of mucilaginous matters, give up their oil with great difficulty, and it becomes necessary to submit the bruised seeds to torrefaction, previous to pressure. The albumen is thus coagulated, and the oil, rendered less viscous, becomes more easy of separation. The latter process, however, requires careful management, or the oils are greatly impaired, both in color and taste.

Until a comparatively recent date, the treatment of oleiferous seeds for the extraction of their oil was by pounding in hard wooden mortars, with pestles shod with iron, and set in motion by cams driven by a shaft turned with horse or water-power. The bruised seed was then transferred to woollen bags, which were wrapped in horse-hair cloth, and squeezed between upright wedges in press-boxes. This arrangement, known as the Dutch mill, has been almost entirely superseded by the hydraulic oil mill and press. In some districts, however, both in this country and on the continent, the old method is still obstinately adhered to, and supposed to be preferable to the hydraulic mills and presses. Some varieties of seed, such as linseed, rape, and other hard seeds, require, before the final crushing, to be passed between iron rollers, in order to crack the shells. The seeds are first introduced into a hopper, through which, by means of a fluted roller, lying across it, they are caused to descend equably between the crushing rollers. These rollers revolve in opposite directions, and are sometimes of different sizes, so that different velocities may be given to their surfaces, enabling them also to draw in different sizes of seed, and to perform their work more quickly. Two scraper blades, are pressed by means of two weights, hanging upon levers, against the surface of the rollers, and remove any seed-cake that may adhere to them. The crushed seeds fall through a slit in the case, and are received into a chest placed upon a board beneath.

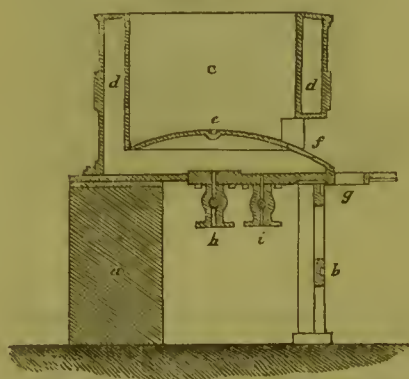
The seed broken by the rollers is passed under two vertical granite millstones or runners—Fig. 375—revolving on a horizontal bed. For accelerating the pulverization, a blade should be attached, and revolve with the stones, for turning up the mass and detaching that which adheres, and returning it constantly into the track of the runners. The two stones, travelling round their circular path, grind the seeds, not merely by their weight, but also by a rubbing motion or attrition; for their periphery being not conical, but cylindrical, they cannot roll on a plane surface without at every instant turning round with a certain amount of friction upon their resting points. Some manufacturers employ stones hooped with iron; but the rough granite surface is much the best. It may be dressed from time to time with hammers as it becomes irregular.

In some cases, and especially when operating upon old seeds, a small quantity of water is added previous to the final crushing, which, taking the place of the oil in the seed, renders the process of extraction much

more easy of execution; sometimes, however, this addition would be injurious. Occasionally, also, the seeds are subjected at once to the runners, dispensing entirely with the previous crushing. When the seed is sufficiently bruised by either or both of these operations, the pasty mass is generally heated in iron pans over an open fire, although the practice is by no means judicious. The object of doing so is principally to coagulate the albumen, which otherwise either retains a large quantity of oil, or itself exudes in admixture with the expressed oil. By heating the bruised seed, the oil is also rendered more limpid, and therefore more easily expressed. The heat of boiling water, however, is sufficient, and either this or steam may be advantageously applied to effect the above purposes; the uniform action of the latter upon the heated pan obviating completely the evils arising from partial and overheating, which always occur at the top and bottom of the common pans.

Fig. 372 is an apparatus designed for this purpose, shown in vertical section. It is known as the steam-kettle of HALLETTE. *a* is the wall of masonry, upon

Fig. 372.

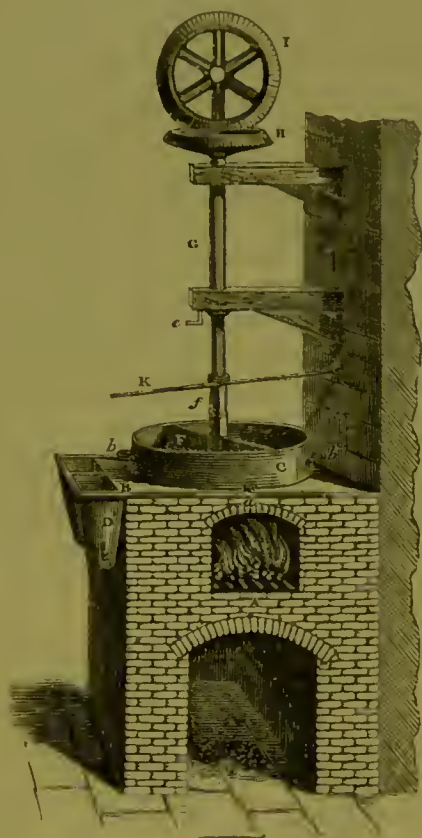


which and the iron pillar, *b*, the pan is supported. It is inclosed in a jacket for admitting steam into the intermediate space, *d d d*, at its sides and bottom. *c* is the middle of the pan, in which the shaft of the seed-stirrer, not shown in the figure, is planted upright, resting by its lower end in the step, *e*. *f* is an opening, by which the contents of the pan may be emptied; *g* is an orifice into which the mouth of the sack or woollen bag is inserted, so as to receive the heated seed when it is expelled by the rotation of the agitator, after the plug, *f*, is withdrawn; *h* is the steam induction pipe; and *i* the eduction pipe, which serves also to run off any condensed water that may collect.

Fig. 373 represents the heating apparatus attached to MAUDSLEY'S seed-crushing mills. In this the seed is heated in an iron pan over the open fire with constant agitation. A cast-iron plate, *B*, called the fireplate, rests immediately over the fireplace, and upon this is placed the ring-pan, *C*, also of iron, for containing the seeds, and which is held immovable by the pins or bolts, *a a*. The agitator, *F*, is employed to prevent the scorching of the seeds by continued contact with the iron plate. It is appended by a turning joint to the collar, *f*, which revolves with the shaft, *G*, and slides up and down upon it. The shaft, *G*, is turned by the

action of the bevel-wheel, *i*, upon the bevel-wheel, *ii*, at the upper end of the shaft. The lever, *k*, is for raising the agitator; and *e*, a catch for holding it in its

Fig. 373.



place when it has been raised to the proper height. The heated seed is removed from the ring-pan by the funnels, *DD*, into which it is caused to fall by pulling the case, *c*, by means of the handles, *bb*, and the bags are suspended to the funnels by means of hooks, *e*.

If fine cold-drawn oil is required, the seed-flour is subjected at once to pressure, without previously heating; but the method most commonly pursued is that given above. The crushed cake is inclosed in a press-cloth or bag previous to its introduction into the case. The bags and cloths used for this purpose are made of different materials, the object being to have them sufficiently strong to bear the force exerted; while, at the same time, they are not so thick or porous as to retain any great quantity of liquid. Woollen cloth is especially manufactured with a view to its application to this process of expression, and is the material usually employed, either wrapped in horse-hair cloth or otherwise.

Several different kinds of presses are used in the extraction of oil, as the screw-press, the wedge-press, and the hydraulic press. Of these the wedge-press is the most frequently employed. It consists of a large press-box, either hollowed out of a strong block of stone or timber, or otherwise constructed of sufficient strength to bear the enormous pressure of the wedges. The bags of seed are placed between iron plates, which are united at bottom in the form of a book cover. These plates are each provided with three side ribs; the immovable ones press against the sides of the case, and the movable against the intermediate wedges; and they are pierced

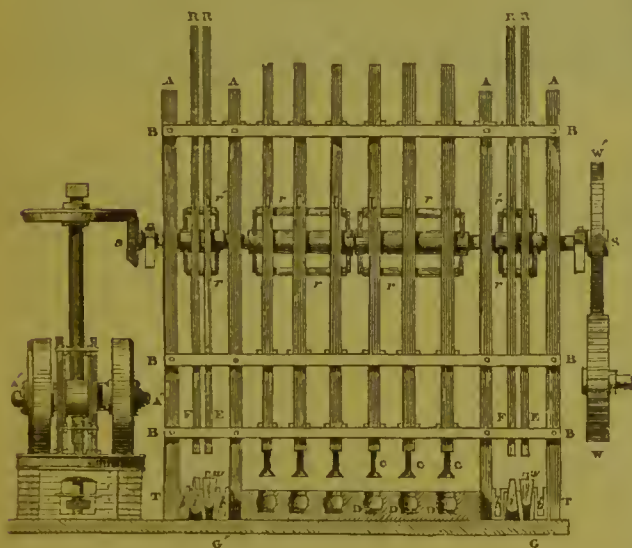
with numerous apertures to allow the oil to percolate more easily.

As the product of oil is, to a certain extent, proportional to the intensity of the pressure, it is more economical to employ that kind of apparatus which gives the most power. The use of either vertical or horizontal hydraulic presses is, therefore, to be preferred to the form of press above described. An important improvement in this press, as used for the expression of oil, has been introduced some time ago, and consists in the employment of double-sided presses, and into the division between the two walls steam is introduced. The press thus heated renders more easy the extraction of the oil. Each hydraulic oil press is usually double—that is, it has two vertical rams placed parallel to each other, so that while the pressure is exerted on one side, the other is being emptied of its contents. The first pump has usually about two and a half inches diameter for a ram of ten inches, and the second pump one inch; both are worked by steam-power, and the pressure exerted is from three to four hundred tons. Many advantages, however, are attached to the use of the old form of press; for it is necessary, in order to accomplish the object efficiently, that the press should be capable of maintaining unrelaxed the degree of compression which has been produced at each successive effort, and that it should not allow the particles, by their elastic force, to regain to any extent their original condition. This quality is possessed to a greater extent by the wedge than by the hydraulic press. The former will maintain for an indefinite length of time any degree of compression which may have been applied to the substance placed in it; but not so the latter. The pressure in the hydraulic press is communicated through a liquid, and maintained by the action of valves, and it is found impossible in practice to prevent a slight leakage, which necessarily diminishes or relaxes the force of the pressure when the pump is not in action. It is necessary, therefore, more frequently to renew the force when conducting the process of expression with the hydraulic press, than is the case with the wedge press.

The oil obtained by the first expression is of the finest quality, and is kept apart from that yielded by subsequent processes. After removal of the flattened seed-cakes from the press and bags, they are returned to the millstones, and crushed and finely pulverized. The fine meal thus produced is submitted to a second compression, sometimes with the addition of a little water, and with the assistance of heat. The temperature to which it is raised is about 155°, and it is constantly agitated by a stirrer moved by machinery. The oil resulting from the compression after this process is of the second quality. In some countries, and particularly in Holland, a still further quantity of oil is extracted, otherwise the soft and fat cakes are sold as food for cattle. The last process of extraction is merely a repetition of the second, except that the pulverized cake is kept for some time at the heat of boiling water, and that a greater pressure is applied than before. The oil obtained is of the lowest quality, and the hard and dry oil-cakes cannot be applied otherwise than as manure.

Fig. 374 is a representation of a mill that may be worked by water-power, wind, steam, or other available means, acting directly on the wheel, *w*, which engages with another wheel, *w'*, mounted on the shaft, *s s*. The stamping or crushing of the seeds is effected by the pestles, *c c*, and mortars, *d d*. The framework, *A A*, supporting the pestles, consists of four strong uprights, bolted firmly together by means of the cross pieces, *B B*. The pestles work in notches attached to the rails, for the purpose of guiding their motion. The raising of the pestles is effected by means of wipers, *r r*, attached to the shaft, *s s*, and so arranged that each revolution raises the pestle twice. The wipers consist of a square socket affixed to the shaft, with arms and rollers at their extremities, so as by avoiding friction to confer greater durability upon the apparatus. When not at work, the pestles are raised by levers, so

Fig. 374.



that the lifts are quite clear of the wipers. The press boxes are similarly constructed to the wedge-presses before alluded to. *E E* are the drivers that strike the wedges, *w w*; and the stampers, *F F*, strike the relieving wedges, *i i*, and serve to disconnect the apparatus. These rams are worked by wipers, *r' r'* affixed to the horizontal shaft. The grinding apparatus, shown in the same figure, is also attached to the machine, and is worked by the same motive power. The running granite stones revolve in a powerful frame-work attached to a vertical axis, which also slowly revolves by the action of a cog-wheel at the extremity of the horizontal shaft upon a similar wheel attached to it. A double motion is thus communicated to the stones—one by which they are carried round upon the bed or floor of the mill, and the other on their own axis. The horizontal axis, *A' A'*, passes through the vertical axis; and to give greater freedom of motion, and to allow the stones to pass over any heaps of seed without straining, the hole for the axle is vertically oval, and of sufficient width. The vertical shaft revolves in a brass bush, laid in the centre of a block of wood; and the horizontal shaft passes through to such an extent, that one of the runners is two-thirds of its own thickness nearer the vertical shaft than the other, and the stones are thus caused to pass over a greater extent of surface than they would, were the

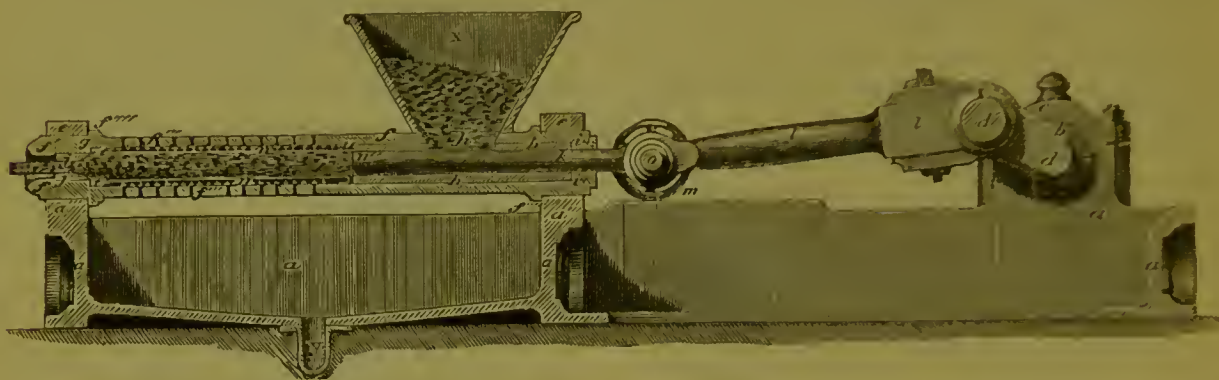
vertical shaft equidistant from each. The seed, spread and dispersed by the motion of the stones, is again brought into their path by means of rakes or sweepers attached to the framework, and revolving on the surface of the bedstone. The inner rake collects the seeds under the outer stone in the form of a ridge, over which the stone passes and flattens it, when the outer rake collects it again into a ridge in the line of motion of the inner stone. The outer rake consists of two parts, one of which presses closely on the wooden hoop of the raised border, and pushes the seed obliquely inwards, while the other part gathers up the grain which has spread towards the centre. The inner rake has a joint near the middle of its length, by which the outer half of it can be raised from the nether stone, while the inner half remains in contact with it, and continues to remove the moist paste. When the seed is sufficiently bruised, the outer end of the rake is lowered and gathers up the paste, and carries it obliquely outwards to the raised border, whence, by an open part of the rim, it falls out into troughs placed to receive it. The latter are perforated at bottom, and a quantity of very pure oil oozes out and is conducted to a cistern apart.

A machine for expressing oils was invented by BESSEMER and HEYWOOD of London, and secured by patent, sealed in May, 1849, in which the materials to be operated upon are forced, by means of a plunger or piston, into and through a pervious vessel which, while allowing the oil to percolate, prevents the passage of other matters through its pores. This oil-press is shown in longitudinal section in Fig. 375. The bedplate or framing, *a a*, which should be cast in one piece, forms at *a'* a cistern for the reception of the oily matters as expressed from the seed or other substance, and at the opposite end of this plate there are projections, *a''*, in which brasses, *b*, provided with caps, *c*, are fitted, and form bearings in which the crank-shaft, *d*, revolves. Two other projections, *a'''*, are also cast on to the bedplate, and are provided with caps, *e*, so as to retain the pressing cylinder firmly in its place. The latter must be of sufficient strength and thickness to withstand the amount of internal pressure exerted. The *lining*, fitted within the cylinder, *f*, consists of a tube of gun-metal, having a spiral groove cut on the outside of it, and having the appearance of an ordinary square threaded screw. At very short intervals all along the spiral groove there are conical holes drilled through the tube, *n*, and communicating with the interior of it. At *tt* the inside of the tube is enlarged, and is provided with a steel collar, beyond which the tube is reduced in diameter. A plain cylindrical bag, with open ends formed of fustian, or other similarly pervious material, is made to fit closely to the inside of the tube, *n*, and within this bag is placed a cylinder of wire-gauze, or finely perforated metal. The steel collar, *t*, is forced into the end of the wire-gauze, by which it becomes driven into the narrow part, and is securely held there by the pressure of the collar, *t*. The bag and wire-gauze are then stretched over the end, *n''*, of the tube, and the collar, *u*, driven tightly on, by which means the bag and wire-gauze are securely held in their places.

The lining tube, *n*, is then put into the pressing cylinder as far as the shoulder, *g*. A tubular piece, *h*, is next put in, and brought into contact with the collar, *u*, and then the gland, *i*, is screwed home, whereby the lining, *n*, is firmly retained within the pressing cylinder. The end of the pressing cylinder is contracted at *f'*, and forms a shoulder for the abutment of the collar, *j*, the diameter of the aperture of which regulates the pressure to which the matters are

submitted. Within the tube, *n*, there is fitted a solid plunger, *k*, which receives a motion from the crank, *d*, by means of the connecting-rod, *l*, the parallel motion being obtained by the wheel, *m*, on the cross-head, *o*, traversing on the side of the bedplate. *x* is a hopper bolted to a flange on the pressing cylinder, and in communication with it there is an opening in the tube, *n*, corresponding with the opening into the hopper, so that the substances placed in the hopper

Fig 375.



may drop into the tube, *n*. Where the plunger, *k*, is withdrawn from beneath the opening at that part of the pressing cylinder which is occupied by the lining, there are drilled numerous small holes, *f'''*, communicating at various points with the spiral groove in the tube, *n*. On the outside of the pressing cylinder there are formed two collars, *f''''*, which abut against the projecting pieces, *a'''*, and caps, *e*, and cause the pressing cylinder to be retained firmly in its place. When steam is the motive power applied to the oil-press, the crank which is actuated by the steam piston is formed on the end, *d'*, on the crank shaft of the oil-press, and placed at such an angle to the crank, *d*, that when this crank is pushing the plunger, *k*, to the end of its stroke, the steam piston will be at half-stroke, whereby the motive power applied will be greatest at the time that the press offers the greatest resistance; and the steam piston, also, when passing its dead points, will have to overcome the friction of the machinery only, as the plunger, *k*, will be in the middle of its back-stroke. If other motive power than steam is applied to turn the crank, *d*, it is necessary to have a fly wheel on the shaft, *d'*, as also such cog wheels as are necessary to connect it with the first mover.

In applying this apparatus to the expression of oily seeds, the latter, after grinding, and heating if necessary, are introduced into the hopper, and motion being transmitted to the crank in the manner before described, the plunger, *k*, commences a reciprocating movement in the tube, *n*, of the pressing cylinder; each time that it recedes in the direction of the crank, it moves from under the opening in the hopper and allows a portion of the seed to fall into the tube, while the reverse motion of the plunger drives it towards the open end of the cylinder, its passage being much retarded by the friction against the sides of the lining of the tube, but chiefly by the contraction of the escape aperture through the collar, *j*; the plunger, therefore, exerts an amount of pressure upon the seed corresponding to the size of the

escape aperture. The expressed oil, passing through the wire gauze and bag, finds its way through the perforations into the spiral channel, and from thence it finds egress by the perforations, *f'''*, in the pressing cylinder, and as it falls is received by the cistern, *a'*, from which it is drawn by the pipe, *y*. Two or more of these pressing cylinders may be used side by side, actuated either by one crank throw, or by separate throws upon one shaft, placed in such a manner as to equalize as far as possible the amount of resistance throughout the revolution of the crank shaft, and instead of the cylindrical pressing plunger, an angular section may be given to the pressing vessel and plunger. Besides its use in the extraction of oil from seeds, this press may be employed in the expression of other matters containing oil.

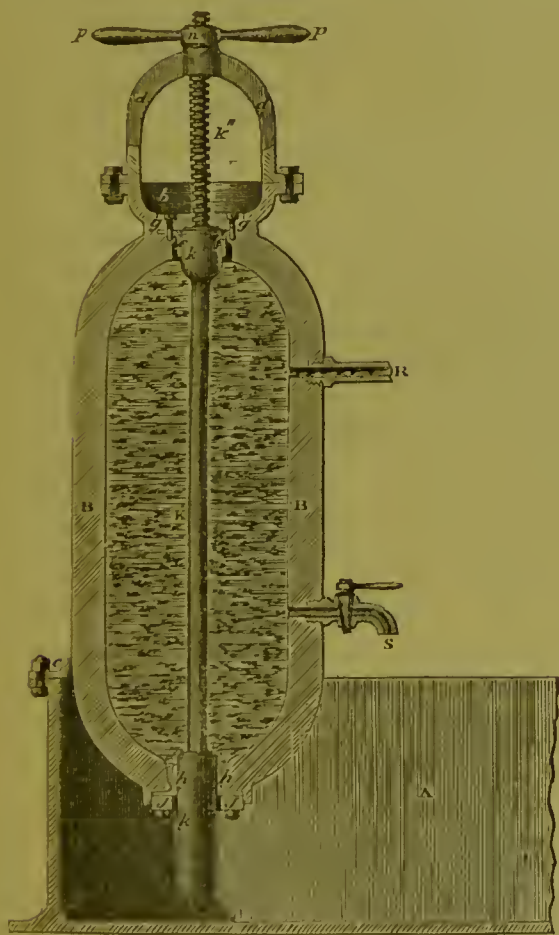
In cases where it is necessary to heat the bruised or ground seed during the process of expression, the pressing cylinder is made of larger diameter and of greater length, and the cistern, *a'*, is divided into two separate compartments, over both of which the pressing cylinder is to extend; a strong wrought-iron tube is inserted in its open end, and extends about half-way to the hopper, where it terminates in a solid pointed end. This tube occupies the centre of the pressing cylinder, and in the annular space around it are the ground seeds or other matters to be pressed. The temperature is raised to the required point by steam let into this iron tube, the end of which, extending beyond the cylinder, is securely attached to a bracket projecting from the bedplate, and is thus held firmly in its place, notwithstanding the force exerted against the pointed end. Thus arranged, the ground seed or other matters falling into the pressing cylinder, are thrust forward by the plunger, and give out a portion of oil in that state known as *cold drawn*, and which falls into the first compartment of the cistern, *a'*; the further progress of the meal along the pressing cylinder brings it in contact with the

pointed end of the heated tube, where it divides and passes along the annular space between the tube and the lining, and being thus spread into a thin cylindrical layer around the tube, it rapidly absorbs heat therefrom, and a second portion of oil is given off and received by the second compartment of the cistern, and thus the two operations of hot and cold pressing are carried on collaterally.

BESSEMER and HEYWOOD's patent further includes a method of treating oily and oleaginous substances for the extraction of their oil, in which the matters to be operated upon are subjected to the action of pressure in water, so as, after temporary admixture of the oil with water, to facilitate the separation of the oil from the matters containing them.

The apparatus used is represented in Fig. 376 in vertical section taken through the centre of the apparatus. It consists of a cast-iron cistern, A, having semicircular ends, and open on the upper side; at one end of it is a cylindrical vessel, B, with hemispherical ends. This vessel is of considerable strength, and should be capable of withstanding a pressure of five

Fig. 376.



thousand pounds to the square inch. It is held in an upright position by a flange, e, formed upon it, and extending round one half of its circumference. This flange rests upon a similar one formed around the upper side of the cistern, A, and is bolted thereto. At the upper part of the vessel, B, is formed a sort of basin, b, the edge of which supports an arch-shaped piece of iron, d. At the centre of the basin is an opening into the vessel, and a hydraulic cup leather, e, is secured

within the opening by means of the collar, g; in the bottom of the vessel, B, there is also an opening into which is fitted a cup leather, h, secured in its place by the ring j, which is firmly bolted to the vessel, B. A strong wrought-iron rod, K, extends from the top of the arch, d, down through the vessel, B, having two enlargements or bosses, k, k', formed upon it, which are fitted to the cup leathers. The upper part of the rod, K, has a screw formed upon it at K'', which passes through the boss, k, and enters the boss, n, in which a screw thread is formed. The boss, n, is provided with handles, p, by turning which the rod, K, may be raised or lowered when required. R is a pipe through which water may be injected into the vessel, B, by a force pump, such as is generally employed to work hydraulic presses. S is a cock whereby a portion of the contents of the vessel may be run off, and the pressure relieved when requisite. The two bosses, k and k', being of equal area, whatever pressure may be exerted within the vessel, B, it does not tend to lower or raise the rod, K, but, acting on the cup leathers, preserves the joint tight, and prevents the matters under pressure from leaking out. This form of apparatus is applied principally in the extraction of the portion of oil remaining in the *marc* or cake that has already undergone the first expression. For this purpose the cake is finely ground, and mixed with as much warm water, or water rendered slightly alkaline, as will reduce it to a semi-fluid state. This is then submitted to the action of the apparatus as follows:—The handles, p p, are turned round, and the boss, k, withdrawn from its opening, while the boss, k', which is much longer, still closes the lower aperture. The semi-fluid materials are then put into the basin, b, and fall from thence into the vessel, B, when it is fully charged. The rod is again lowered, and the communication with the hydraulic press pump is made by means of a tap attached to the pump, from which the water flows through the pipe, R, into the vessel, B, and thus, with a few strokes of the pump, the whole of the contents of this vessel will be subjected to the requisite pressure. An interval of a few minutes is allowed for the combination of the oil and water; the cock, S, is then opened, and a small portion of the fluid contents of the vessel allowed to escape into the cistern; the pressure being thus relieved, the handles, p p, are again turned, so as to lift the rod, K, sufficiently high to withdraw the boss, k', from the lower opening. The contents of the vessel, B, then flow out into the cistern, A, and the boss, k', being again lowered so as to close the lower aperture, the vessel may be refilled for another operation. The pressure thus brought upon the mixture of oleaginous matters and water will cause the oil therein contained to mix with the water, and the former may be afterwards separated from the milky-looking fluid, either by repose in suitable vessels, or by evaporation of the water by heat. If the oil is required for soap-making, the mixture of it with the water may be applied without separation. After the materials have been withdrawn from the cistern, A, and strained, the solid portions are again submitted to pressure, and from the expressed liquid the albumen is removed by boiling, and the oil separated as before.

H. W. Wood, of London, some years ago invented a process for the extraction of certain oils from seeds, in which diluted acid is applied to the seed, previous to pressure; whereby, according to the patentee, the seed will part more thoroughly with the oil. The process is as follows:—During the grinding of the seed, it is regularly sprinkled with the dilute acid, in the proportion of two ounces of hydrochloric acid, of specific gravity 1.160, mixed with six and a quarter pounds of water to every hundred pounds of seed. The mixture of seed, acid, and water is permitted to stand for a longer or shorter period, depending on the quality of the seeds, usually not more than twelve hours. The mixture is then submitted to pressure in bags, the latter being placed alternately in the press with plates of iron. A hydraulic press is preferred. By this treatment, a more than ordinary quantity of oil is said to be obtained from a given weight of seed.

Amongst the great number of oils now known, there are several which are admirably suited for various purposes, but which nevertheless, on account of their price, depending usually on local circumstances, such as cost of freight, *et cetera*, are very little or not at all used by our manufacturers. Should, however, accidental circumstances at any time occasion an advance in the price of the more common oils, some of those above alluded to might be procured in large quantities, and would probably, in a short time, altogether supersede many of the oils now in use. Whilst, therefore, it is desirable to draw the attention of manufacturers and consumers to the numerous foreign and colonial oils not at present well known in this country, it is, at the same time, important to point out how greatly the value of such oils depends on the care bestowed on their preparation, especially as regards cleanness of the seeds, and the careful exclusion of impurity of all sorts in the process of extracting the oil.

PURIFICATION OF SEED OILS.—Many oils in their natural state are always more or less impure, and some of them so viscous as to be quite inapplicable to the lubrication of machinery, or to illuminating purposes, without previous purification. The impurities consist for the most part of albuminous, mucous, gelatinous, and coloring matters. A great part of the mucilaginous matters, and all bodies merely in a state of suspension, are deposited by repose for a sufficient length of time; but in order completely to clarify the oil, it is necessary to employ other means of depuration. The method most generally adopted is that suggested by THENARD. As already noticed, the concentrated acids exert a remarkably energetic action upon the combustible oils; if the power of these acids, however, is weakened by lessening the quantity used, the foreign matters in admixture are then chiefly affected. Sulphuric acid, for example, in the proportion of one or two per cent. of the oil, acts as a depurating agent, precipitating the mucilage and parenchymatous matters; first, by its powerful dehydrating action, it removes the water, by which these substances were held in solution in the oil, and afterwards chars the mucous matters themselves, thus either rendering them insoluble, or otherwise effecting their destruction. The oil itself is also to a certain extent acted upon: it

becomes green or dark brown, and after some time yields a deposit of the same color, becoming itself perfectly bright and clear. THENARD'S purifying process is conducted as follows:—The oil, first heated to 100° or upwards, is placed in a convenient vessel, and from one to two per cent. of sulphuric acid is gradually poured in, with constant and violent agitation. As the action of the acid depends more or less upon the amount of contact between the two liquids, as well as upon the degree of heat, it is, of course, desirable to employ such an apparatus as will allow the easy and rapid admixture of the oil and acid. This is best supplied by an agitating tub, movable round its own axis, or it may be fixed immovable, but with a movable fan in its axis. When, after continued agitation, the dark-colored oil appears to consist of a clear liquid, holding flocculent matter in suspension, the action of the acid is terminated. This, however, is perceptible only after about twenty-four hours' repose. At the end of this period, a quantity of water, heated to 140°, and equal to about two-thirds of the oil, is added, and the mixture is agitated until it acquires a milky appearance. After several days' repose, the clarified oil rises to the surface of the mixture of acid and water, and the black flocculent matter forms a deposit beneath the two liquids. The oil, however carefully it may be decanted, always requires to be filtered to remove the matters still held in suspension. To effect this operation, the oil is drawn at once from the depositing tubs into vats with conical openings in the bottom stopped with cotton plugs, or it is passed through baskets lined with moss or carded cotton. The filtration is always a difficult operation, the plug-holes becoming quickly and repeatedly choked with the solid matters. A much better method is to pass the oil through a displacing funnel, the apertures in the diaphragm of which are furnished with filaments of carded wool or cotton. By some manufacturers a modification of THENARD'S process is pursued, which consists in neutralizing the sulphuric acid by the addition of a mixture of chalk and water, or milk of lime. The operation is then concluded in a much shorter period, and the separation of the oil and water is far more complete.

The black deposit produced by the action of sulphuric acid, after having been heated and subjected to pressure, yields about eighty per cent. of oil, which, after clarification and filtration, is little inferior to the oil first obtained.

COGAN'S modification of THENARD'S method of purification is designed to obviate the difficulty of getting rid of the charred matter and excess of acid employed. Steam is the agent made use of: and by its judicious introduction the oil appears to be almost entirely freed from acid, and the black feculent dregs subside in the course of twelve hours, leaving the supernatant oil quite clear and greatly improved in color, and in those qualities for which it is valued by the painter. The two combined processes are conducted as follows:—The quantity of oil operated upon is about one hundred gallons. For this about ten pounds of sulphuric acid are required, and this is diluted with an equal bulk of water. To the oil, placed in a convenient vessel, one-third part of the dilute acid is added, and

the whole is carefully stirred for an hour or more with a wooden scoop, till the acid is thoroughly incorporated with the oil, and the latter has assumed a darker color. A second similar quantity of acid is then added and mixed with agitation as before, and after this, the remaining third of acid is poured in. The stirring is now continued incessantly for two hours more, when the color of the mixture resembles that of tar. It is allowed to stand at rest for twelve hours, and then transferred to a copper boiler. This latter has a steam pipe entering at the bottom, which divides into three or four branches, each terminating in a perforated plate. Steam is forced through this pipe, and, passing in a very divided state into the oil, penetrates into every part of it, and raises the temperature to 212°. The steaming process is continued for about six hours, at the end of which time the oil is transferred to a cooler, of the shape of an inverted cone, terminating in a short pipe, provided with a stopcock inserted in its side a few inches from the bottom. After standing twelve hours, the black watery acid liquor is withdrawn by opening the stopcock at the bottom. The clear and limpid oil is then drawn off by opening the tap in the side of the cooler. What remains below this cock is turbid, and this, being let out into a reservoir, is either clarified by subsidence, or mixed with the next portion of raw oil.

The quality of oils to be used for the lubrication of machinery, or for illuminating purposes, is much improved by the application of solution of tannin, by which the foreign matters are rendered more completely insoluble. In this process a strong infusion of nutgalls is mixed with the oil by agitation. After deposition the clear oil is decanted from the precipitate, and similarly treated with a solution of acetate of lead, acetate of alumina, or sulphate of zinc, to remove any excess of tannin. During these operations, the oil should be kept as near 70° as possible. The oil is afterwards dried by agitation with freshly-calcedined sulphate of lime, or anhydrous carbonate of soda, which are allowed to deposit by rest. The addition of from five to ten per cent. of essential oil, or of a hydrocarbon—as mineral naphtha or oil of turpentine—to oils purified as above, renders them much more valuable as sources of light. They are intimately mixed either by agitation, or by passing the hydrocarbon in the state of vapor into the oil.

The treatment of oils and fatty matters, by submitting them to the action of streams of air or steam, is an efficient method of purification and bleaching. This mode of treatment was adopted by T. J. KNOWLYS of Lancaster, who, some years ago, obtained a patent for a process for clarifying and improving the quality of linseed and other oils to be applied in the manufacture of paints, varnishes, *et cetera*, by exposing the oil to the conjoint action of light and air. To this end the oil is first heated in the usual manner, or mixed with a portion of manganese or litharge, which are left to react upon it for a few days, and then separated by straining. The filtered oil is then exposed to the action of light and air, or steam, in a suitable vessel, and with constant agitation, so as to present continually a fresh surface.

OLIVE OIL.—*Huile d'olives*, French; *olivenöl*, *baumöl*, German; *oleum olive*, Latin.—Olive oil appears to have been known from the remotest antiquity. The olive tree—*olea europæa*—is one of the prettiest in nature. Very few vegetables have been so repeatedly noticed or so enthusiastically described by the ancient writers, and from the earliest ages it has been adopted as the emblem of benignity and peace.

The precise period of the discovery of olive oil, and of its application to the wants of man, is not recorded. It appears to have been known from the earliest times, since the method of producing it is mentioned by MOSES, and what is very remarkable, it is, with slight variation, the process employed at the present day. It is obtained from the bluish or brownish green integument, or sarcocarp, of the fruit or olives. Several varieties of olives are met with in commerce, but the most common is the small French *olea europæa longifolia*, and the large Spanish *olea europæa latifolia*. The ingathering is performed in different ways, according to the kind of oil to be extracted. If the olives are gathered some time before they are ripe, they yield an oil with an acrid and bitter taste. When more ripe, but still before they arrive at maturity, the oil possesses the peculiar taste of the fruit, and may be preserved for a lengthened period without becoming rancid. When fully ripened, so as to drop from the trees, they yield a fine oil, but more fatty, and also more susceptible of change by exposure. November and December are the principal harvest months, and if allowed to remain longer on the trees, the olive gradually deteriorates, and yields an oil of very inferior quality. To obtain the finest oil, the olives should be gathered by hand, for if bruised, as in the usual method of beating the fruit from the trees with poles, unless used directly, they ferment, and the oil acquires a highly disagreeable odor and taste.

The process for procuring olive oil is somewhat modified in different countries, though the principle is the same in all, namely, for the purest, gentle pressure of the freshly gathered fruit in the cold; for common or second oil, stronger pressure, aided by partial fermentation of the olives, and the heat of boiling water; and for another still inferior kind, by boiling the husk or *marc*, after the preceding treatment, with water, when a mucilaginous oil rises and floats on the surface. All the varieties are left to repose for a month after being extracted, in order that the impurities may subside.

The following is the method pursued in the South of France:—The ripe olives are crushed in a mill of the most rude construction, comprising usually a single millstone turning in a circular bed; sometimes two millstones, placed wide enough apart not to crush the seeds. The workmen remove all the pulp when sufficiently crushed, and place it in rush sacks, which are heaped up, to the number of eighteen or twenty, on the platform of a press. This is also of a very rude description, and is only capable of a very slow and feeble pressure. The oil which first exudes from the bags, when the olives are of good quality, and the pressure is nicely regulated, is the variety known as salad oil, and is much in request for the supply of the table. After the first pres-

sure, the pulp still contains a considerable quantity of oil, so mixed with albuminous matters that it cannot flow out. To extract a portion of this oil, the press is taken apart, the cakes are broken up in the bags, and the nearly dry residue is digested with boiling water, and again pressed as before. The boiling water being absorbed causes the pulp to swell; the albumen coagulates, and the more fluid oil runs out freely. This operation is repeated two or three times. For the reception of the water containing the oil, two tanks are used, so arranged that in the one the liquids separate into two layers, whilst the other is filling. The upper layer, consisting of oil, is ladled off, and the water below, which still contains oil in suspension with mucus, is collected for further separation into a narrow and deep cistern, from which the water can be removed by a long siphon. After deposition of a portion of water, it is drawn from underneath, the cistern is again filled with a further quantity of the mixture, and when a sufficient quantity of oil swims on the surface, it is skimmed off, as oil of inferior quality. Owing to the imperfections of these processes, a quantity of oil still remains in the refuse in the bags, and the producers of oil find it worth while to submit it to a third operation. The large amount of time and labor consumed in the complete exhaustion, and the fact that the oil obtained is not of as good quality as it might be, has induced DUMAS to give his attention to this subject, and he has suggested several improvements in the old method of extraction. This eminent authority recommends, for the crushing of the olives, the use of mills of similar construction to those employed in the extraction of oil from seeds; and instead of the common presses, he proposes the employment of horizontal hydraulic presses, or of the wedge presses used to remove the oil from crushed seeds, by means of which the oil would be withdrawn more easily and rapidly, and the exhaustion would be much more complete.

The last operation, in the method usually employed, is as follows:—The cake or *mare*, after the second pressure, is immediately moistened with water, as a preventive of fermentation, which otherwise quickly ensues, and effects the destruction of the last traces of oil. The absorption of water is accelerated by heaping the moistened cake in layers in vats. The next step is the separation of the stones: this is effected by means of two machines, adjoining each other, and worked by the same motive power. The first consists of a vertical millstone turning in a pit of masonry or woodwork, through which flows a current of cold water. The cake passed through this is conveyed through a trap-door into the other machine of similar construction to the first, except that the crusher is heavier; and there is attached to the axle an arm, which serves to agitate the paste with the water. In this process the broken stones fall to the bottom, whilst the lighter parts, with the kernels of the seeds, rise to the surface, and are removed by means of hair sieves. These mucous matters are dried over a fire, until they form a stiff paste, which is then submitted to pressure as before. The oil thus obtained is applied to lighting purposes, and in the manufacture of soap. By the adoption of

the improvements suggested by DUMAS, he considers that this last very tedious course of operations might be entirely dispensed with, and still the same quantity of oil would be obtained, and that of superior quality. Another very desirable improvement would be effected if the growers themselves would extract the oil, instead of, as is usually the case, sending the fruit to the common miller. At these mills they are often allowed to remain in heaps for some days, or until the mill is at liberty; from which cause the oil is of far inferior quality than would otherwise be obtained.

In Naples, the machinery employed by the peasant in the preparation of Gallipoli oil is of the rudest kind. The olives, when ripe, are allowed to drop from the trees, and are collected and conveyed to the mill, chiefly by women and children. The oil, when expressed, is inclosed in sheep or goat skins, and carried on mules to Gallipoli, where it is allowed to clarify in reservoirs cut in the rock on which the town is built, and its ultimate value depends, in a great measure, on the nature of this cistern. In point of fact, Gallipoli owes its celebrity to the facility of the formation of these cisterns, as in them the oil soon clarifies, and may be preserved for a lengthened period without becoming rancid.

The finest olive oil is of a pale yellow color, sometimes inclined to green. It has scarcely any smell, but a bland, mild, and agreeable taste; occasionally it has a nutty flavor, and when swallowed, leaves a slight sense of acrimony in the throat. It is insoluble in water, slightly soluble in alcohol, and in one and a half times its weight of ether. Its specific gravity is 0.910 at 60°. At 36° it deposits white granules, especially if heat has been applied in its extraction. At 22° it deposits twenty-eight per cent. of its weight of margarin, fusible again at 68°, and it yields also seventy-two per cent. of olein. Of the different kinds of olive oil met with in commerce, the produce of Aix, known as Provence oil, is the most esteemed. Florence oil, imported from Leghorn in flasks, packed in chests containing thirty of these, is a very fine kind, used for culinary purposes. Lucca oil is imported in jars holding nineteen gallons each. Gallipoli forms the largest proportion of that brought into this country, and is imported in casks. Puglia and Calabria are the provinces of Naples most celebrated for its production. Sicily oil is principally produced at Milazzo, and is of inferior quality. In some countries, and especially on the continent of Europe, olive oil constitutes an important article of diet. It is extensively used in England in the manufactures, and especially in the treatment of woollen cloths. The inferior kinds are much used in the production of soaps, particularly of the varieties known as Marseilles and Castile soaps. Being less liable to become thick and viscid by exposure to air, it is often used for oiling delicate machinery. For application to watch and clock work, the oil is refined by cooling, separating the fluid portion, immersing in it a slip of sheet lead, or some shot, and exposing it to direct sunlight in a corked phial, when a whitish matter gradually subsides, and the oil is rendered clear and colorless. This, when decanted, is fit for use.

PETER BAXCROFT, of Liverpool, in 1846, patented a

process for purifying olive oil, which consists in treating the oil, heated to about 90°, with a strong solution of potassa or soda, either as carbonate or in the caustic condition, giving preference to the latter, as it operates more quickly. The specific gravity of the solution may be 1·2 or even stronger. The oil is kept constantly agitated during the addition of the alkali, and the operation is at an end when a small portion of the oil, placed in a glass bottle, and shaken with a further addition of solution of alkali, deposits only a clear liquid, free from soapy matters. The quantity of solution of alkali required varies from three and a half to eight per cent. The oil is decanted after deposition of the soapy matters, and passed through a filter. So treated, this oil is said to be very valuable as a lubricant for machinery.

Adulterations.—The superiority of olive over other kinds of oil, and its higher price, render it liable to adulteration with rape and poppy oils, and especially with lard oil—what is called *superfine* Lucca oil often containing as much as sixty or seventy per cent. of the latter. Several methods have been proposed to detect these sophistications. Poppy oil may be discovered by the phenomena of *beading*, or the appearance of a number of air bubbles on the surface after violent agitation of the oil, which are not produced with pure oil. GUIBOURT recommended congelation, but this test is ineffective unless the adulterant is present in large quantity. The most reliable test is that suggested by POUTET, which depends upon the peculiar action of nitrous acid upon olive oil. A nitrate of mercury is prepared by dissolving six parts of quicksilver in seven and a half parts of nitric acid, of specific gravity 1·36, without applying heat. When one part of this freshly prepared solution is added to ten parts of pure olive oil, the mixture becomes concrete in the course of a few hours. The admixture of foreign oils prevents this congelation, so that the resulting mixture is more or less liquid in proportion to the quantity of the adulterant present. The twentieth part of poppy oil is easily detected by this method, but, in order to arrive at satisfactory results, a comparative experiment should be made with a mixture of oils of known composition. Other methods will be given when treating generally of the adulteration of oils and fats.

Physiological Effects.—According to Dr. BEAUMONT, olive oil is extremely nutritious, but rather difficult of digestion. However, when taken as a condiment with salad, it promotes the digestibility of the latter. In larger doses, olive oil acts as a gentle laxative, with freedom from pain. It is often administered in cases of irritant poisoning, as an emollient and demulcent, to shield the stomach from the action of acid and corrosive substances.

Statistics.—The quantity of olive oil imported annually, from the years 1844 to 1850 inclusive, was as follows:—

	Gallons.
1844,.....	3,770,424
1845,.....	3,103,380
1846,.....	2,150,568
1847,.....	2,190,384
1848,.....	2,541,672
1849,.....	4,271,928
1850,.....	5,237,316

ALMOND OIL.—*Huile d'amandes*, French; *mandelöl*, German; *oleum amygdalæ*, Latin. This oil is obtained by expression from the seeds of the *amygdalus communis*, either sweet or bitter, usually from the latter, on account of their comparative cheapness, as well as of the greater value of the *marc* or pressed cake. Almonds were well known to the ancients, and are alluded to in the writings of MOSES—Genesis xliii. 11. HIPPOCRATES employed the expressed oil, as well as the almonds themselves, both sweet and bitter, in medicine. DIOSCORIDES describes the method of extracting the oil.

ROBIQUET discovered in bitter almonds from one to 2·5 per cent. of a peculiar principle not contained in the sweet variety. This principle, which is termed amygdalin, is a colorless, crystalline, nitrogenous body, with a bitter taste, and free from odor.

The fixed oil of almonds is obtained by expression from either kind; and if contact of water be carefully avoided, the oil from the bitter is quite as bland as that from the sweet variety. The almonds, previously cleansed of the adherent furz and dust by being well shaken and sifted, are bruised or coarsely powdered, and pressed in hempen cloths or bags, between iron plates, either cold, or, preferably, slightly and uniformly heated by hot water or steam. The yield of oil varies from twenty-eight to fifty-four per cent. When recently expressed, this oil is turbid, but by rest and subsidence becomes quite transparent. The mucilaginous matter should, however, be separated as quickly as possible, as it promotes rancidity; and the oil should be preserved in well-stopped bottles.

Almond oil is pale yellow and very fluid, inodorous when fresh, and of a faint oleaginous taste. It quickly becomes colorless by exposure to light. It remains fluid at a much lower temperature than olive oil, but at 14° it deposits twenty-four per cent. of concrete matter. Its specific gravity at 60° is about 0·918. Cold alcohol takes up about a twenty-fourth of its weight, and boiling alcohol a sixth. It is also very soluble in ether. Its principal use is in pharmacy, as an ingredient in emulsions, and occasionally in liniments, ointments, and soaps. As it contains less margarin than olive, it yields softer soap, and is better adapted to the preparation of oleic acid. The cake left after expression of the oil is sometimes ground, and is known as almond powder, and used as a detergent for preserving the skin soft and pliable.

Adulterations.—Commercial almond oil is frequently adulterated to a considerable extent with lard or olive oil; indeed, according to MORFET, what is sold as the genuine article is often olive oil, merely flavored with that of almonds. According to PEREIRA, teal oil, or oil of *sesamum*, is occasionally substituted for almond oil, from which, however, it may be known by the deposit of margarin being formed much more readily than in oil of almonds.

Physiological Effects.—Almond, like olive oil, is highly nutritive, but difficult of digestion. It possesses also the medicinal as well as dietetical qualities of olive oil. In large doses it is a mild laxative. Its local action is emollient. It is employed medicinally for the same purposes as that of olive. Sometimes it is

administered to allay cough, or as a laxative, but, according to CHRISTISON, is not well adapted for either purpose. It is also used for outward friction, and for cosmetic soaps.

RAPE OIL.—This oil is prepared from the seeds of several species of the genus *brassica*, belonging to the family of *crucifera*, as the *brassica napus*, or winter rape, and the summer rape, or *brassica praecox*. Besides oil and woody fibre, these seeds contain a considerable quantity of mucus, albumen, and other allied substances. Only the driest possible seeds, such as have been stored for several months, and protected from moisture, are expressed. It is usual also to submit the seed to steam heat previous to pressure, as, if the albumen present is not completely coagulated the oil obtained is much less in quantity, and far inferior in quality, to that otherwise extracted. The very large proportion of fluid contents, other than oil, contained in fresh seed, constitutes the great difficulty in obtaining an average oil both as to quantity and quality; but by the above method of treatment this obstacle is overcome, and the oil expressed, containing only a trace of albumen, and a greatly-reduced proportion of mucus, becomes comparatively easy of purification. As newly expressed, even with every precaution, it is viscid, owing to the mucus and other foreign matters unavoidably present. These, and the coloring matter also retained by the oil, lessen its combustibility, and occasion much smoke during its burning.

Purification.—Rape oil is most conveniently depurated by the process recommended by THENARD, and already described. A two-hundredth part of sulphuric acid is added, and the mixture well agitated; it is then left at rest for about twenty-four hours, and afterwards shaken with two-thirds of its bulk of water at 160°. The emulsion thus produced, after standing about eight or ten days in a situation the temperature of which is maintained at 80°, separates into two portions, when the upper layer of clarified oil may be drawn off and filtered through a displacing funnel, the apertures in the diaphragm of which are furnished with filaments of carded wool or cotton, and is then fit for use. In this operation the coloring matter is deposited in the form of dark greenish flocculi, which, by the action of the sulphuric acid, are converted into an insoluble state.

Another mode of treating the several varieties of rape oil has been recommended by DEUTSCH, by which it is said to be rendered more applicable to the several manufacturing and other operations in which it is employed. His process is as follows:—The oil is placed in a copper pan or boiler, and fire-heat applied until the oil begins to be decomposed, when the heat is so regulated as to keep the oil in a uniform state of ebullition for about three or four hours. The spongy scum which separates, after a time begins to subside, whilst the oil becomes clear and transparent, and of a green color. The fire is then removed, and the oil is allowed to settle for one or two days, when the clear green oil is drawn off. If the oil has not acquired a green color, it is an indication that the process has not been well performed, or that the oil employed was of inferior quality. The several varieties of rape oil, after this treatment, may be advantageously employed

for the oiling of wool in the process of its manufacture, and they may also be employed for the lubrication of machinery. For the latter purpose, if it be desired to diminish its fluidity, a solution of caoutchouc obtained by boiling the latter in the oil, may be added to the oil, which should be heated and well stirred, to effect a uniform mixture. The oil may be rendered less fluid by mixing it with tallow or other grease.

WARBURTON'S method of effecting the purification of rape oil is by treatment with caustic alkali, in which the albuminous and other impurities are soluble, and are separated, associated with soapy matter. In a suitable vessel, containing fifty-two parts of caustic soda solution, of specific gravity 1.010, are to be put one hundred pounds of the refined oil; these are to be stirred with a wooden ladle till well mixed. The mixture is then allowed to stand twenty-four hours undisturbed, in a cold place, after which it is then slowly warmed, and again well stirred. After twenty-four hours' subsidence all the oil will have separated; if such should not be entirely the case, the complete separation may be effected by the addition of a small quantity of spirit of wine. The oil drawn off from the liquor is afterwards well washed with hot water, till the pure oil is obtained without taste or color, and if desired, may be passed through a filter. The soap which deposits may be used as an ordinary detergent.

Rape oil is of a light-yellow color and has a peculiar taste and smell. The smell becomes much stronger when the oil is heated; and the color darkens to greenish-yellow when the temperature is increased to 398°. The specific gravity of that from the *brassica napus* is 0.9128 at 60°, and from the *brassica rapa*, 0.9167. It contains forty-six per cent. of solid fat, which congeals at about 28°, but requires to be heated to about 43° before it again fuses. It is employed in the manufacture of woollen goods; in the preparation of some kinds of leather; for oiling machinery; in the production of soap; and also for burning. After purification from mucilage, *et cetera*, rape oil is said to be better suited for the lubrication of machinery than any other oil. It is now extensively used for locomotives, for marine engines, and also as lamp oil. According to Mr. BROTHERTON, a manufacturer of oils, good English-grown rape seed yields oil of superior quality to any foreign seed ever brought to his notice, and he consequently recommends its cultivation to agriculturists. The inferiority of the oil obtained from Indian or colonial seed probably depends, in a great measure, on the want of sufficient care being paid to the purity and cleanness of the seed itself, and not to any real deficiency in the oil.

Colza oil is extracted in the same manner as the preceding from another variety of seed of the same genus of plants—the *brassica campestris oleifera*. It is produced in France in large quantity, and is used for the same purpose as rape oil. It is of a yellow color, and nearly free from odor. Its specific gravity is 0.9136 at 60°. It congeals at about 22°. It is sparingly soluble in cold alcohol, but readily soluble in this fluid when assisted by heat. Colza oil is largely used for illuminating purposes, and may be burned without previous purification.

A Parisian, named NUERBERGER, in 1856, obtained a patent for the extraction of oil from the seeds of other genera of the order *crucifera*. This oil forms a substitute for colza oil, and may be used for lighting and other purposes. The three genera from which the oil may be procured, are the genus *thlaspi*, or shepherd's-purse; the genus *capsella*, or common shepherd's-purse; and the genus *iberis*, or candy tuft. The species *capsella bursa pastoris* yields the largest proportion of oil. The latter is obtained precisely as colza oil, and is also purified in the same manner.

Teel Oil, or Oil of *Sesamum*.—The plant yielding this oil, the *sesamum orientale*, is extensively cultivated throughout India for the sake of the fine oil expressed from its seeds. The latter are imported from Calcutta under the name of teel seeds. They are about the size of white mustard seeds. Three varieties are known—namely, the white, the particolored, and the black. It is principally from the latter that the sesamum oil of commerce is obtained. The seed contains about forty-five per cent. of oil. This has been already mentioned as an adulterant of almond oil, and, according to PEREIRA, may be used as a substitute for the latter.

Oil of *Behen* or *Ben*.—This oil is obtained by expression from the decorticated seeds of the *mohringa aptera et oleifera*, a tree resembling a willow, and indigenous to Arabia and Syria, but cultivated also in the West Indies. The oil is colorless and inodorous, and has an agreeable flavor. By repose it separates into two portions, one thick and the other fluid at very low temperatures. The latter, as it resists the rancidifying action of the air, is highly valued for lubricating watch and clock work. The oil itself is much esteemed as an agent for the extraction of the delicate perfume of certain flowers by the process of maceration. It is also used as the base of macassar oil. Oil of ben contains a peculiar fat, named moringin, which, by saponification and decomposition of the soap, yields moringic acid. This acid is solid at 32°.

Beech Oil.—This oil is obtained from the nut of the *fagus sylvatica*, or beech-tree. It is extracted either by cold or hot expression of the nut, previously decorticated. The percentage yield is about sixteen. The oil is of a clear, yellow color, is inodorous, but has a slightly acid taste, which, however, is dissipated by keeping or by ebullition with water. Its specific gravity is 0.9225 at 60°. At 29° it becomes solid. It is not well known in this country. In some districts of France, however, it is extensively used for culinary purposes, as well as for the production of soap and as a source of light. The cake remaining after expression of the bruised nut is useful as food for cattle.

Oil of Mustard.—This oil is procured by expression of the bruised seeds of the black or white mustard. The mustard plant—*sinapis*—of which there are several species, appears to be indigenous to this country. It was formerly cultivated in Durham, but is now grown principally in the neighborhood of York. In India and the East, mustard is cultivated solely for the sake of the fixed oil it contains. The seeds of black mustard were first analysed by THIBIERGE, and have been since examined among others by PELOUZE, ROBIQUET,

BUSSY, and FREMY. From their labors we learn that this seed contains myronate of potassa, myrosin, fatty, gummy, and coloring matters, a peculiar green matter, sugar, sinapisin, free acid, and salts. The proportion of oil is about twenty-eight per cent. of the seeds. According to the analysis of JOHN, white mustard seeds consist of an aerid volatile oil, yellow fat oil, brown resin, gum, extractive ligneous fibre, albumen, free phosphoric acid, and salts. ROBIQUET and BOUTRON, however, have proved that white mustard does not contain volatile oil, nor any substance capable of producing it. The yield of oil from white mustard seed is about thirty-six per cent. Oil of mustard is of a reddish or brownish yellow color, and is nearly inodorous. It has a thick oily consistence, and may be preserved for a lengthened period without becoming rancid. Its specific gravity is about 0.916. It requires one thousand parts of alcohol at 0.90 for solution, but dissolves in four parts of ether. By saponification glycerin is eliminated, and by decomposition of the soap produced, *erucic acid* is liberated. The formula for this acid is $C_{44}H_{41}O_3$, HO. It forms acicular crystals which fuse at 93°. Oil of mustard may be applied to the same purposes as rape oil; it has been used in the manufacture of soap, and also medicinally as a purgative and anthelmintic. The expressed mustard cake, owing to its acidity, is unfit for food for cattle, and is only useful as a manure.

Cocoa-Nut Oil is extracted from the kernels of the cocoa-palm—*cocos nucifera et butyracea*—either by expression or by ebullition with water. The cocoa-palm is a native of tropical countries, but does not thrive except near the coast. Five varieties are indigenous to Ceylon. The bark yields a peculiar oil used by the Cingalese in the form of ointment in cutaneous diseases. The nucleus or kernel of the cocoa-nut has been analysed by BRANDES, BUCHNER, and BIZIO, and according to the latter authority is composed as follows:—

	Centesimally.
Oil,.....	71.488
Zymome,.....	7.665
Mucilage,.....	3.588
Crystallizable glycerin,.....	1.595
Yellow coloring matter,.....	0.325
Ligneous fibre,.....	14.950
Loss,.....	0.389

Albumen of cocoa-nut, 100.000

In Malabar and Ceylon two methods of extracting the oil or cocoa *butter* are practised; the one is by pressure, the other by boiling the bruised nut, and skimming off the oil as it rises to the surface. The kernels of this palm are also brought to Europe, and the oil is extracted by the aid of heat, the fruit having been previously ground or cut into small pieces. The oil, as shown by TINDALL, consists of a fluid and a solid fat, which are most probably distinct and separate in the seeds, but become mixed under the press, and so much the more the higher the temperature is raised; so that fluid or solid fat, or such as is of medium consistence, may be obtained as desired, and according to the amount of pressure applied, and the temperature at which the operation is conducted. Commercial cocoa-nut oil is concrete at temperatures

below 69°, and at about 74° is fluid. The solid constituent of this oil varies from that of other oils, and is named cocostearin or cocosin. The principal use of cocoa-nut oil is in the manufacture of soap and candles. As a material for the production of soap, it is in many respects valuable, the soap being brilliant white, very hard and light, and to a larger extent soluble in saline and alkaline waters than most other soaps, and consequently useful for washing in salt water. Cocoa-nut oil has also been used as a therapeutic agent, and by some is considered little inferior to olive oil. On the continent of India, as well as in Ceylon, it is used as a pomatum for promoting the growth of, and preserving and softening the hair. It is stated also, that if it were perfumed, and used for this purpose by Europeans, its virtues would be displayed to such advantage as to insure its general use. Its odor, and the rapidity with which it becomes rancid, are, however, a great objection to its employment, either in medicine or as a pomatum. The olein of cocoa-nut oil, which remains liquid at ordinary temperatures, cannot be burned in an argand lamp of ordinary construction, in consequence of its charring the wick: with a view to cheapness, and to combustion in what is known as the solar lamps, it may be employed in admixture with spermaceti oil, but the latter is deteriorated in proportion to such addition. Cocoa-nut oil is a very complex fat, yielding, according to GEORGEY, no fewer than six acids on saponification. These acids are—

Caproic acid,	$C_{12} H_{24} O_2$	HO
Caprylic acid,	$C_{16} H_{32} O_2$	HO
Rutic acid,	$C_{20} H_{40} O_2$	HO
Laurostearic acid,	$C_{24} H_{48} O_2$	HO
Myristic acid,	$C_{28} H_{56} O_2$	HO
Palmitic acid,	$C_{32} H_{64} O_2$	HO

Cocosin or cocostearin is separated from the liquid portion of cocoa-nut oil by pressure, by ether, or by solution in boiling alcohol, from which the stearin crystallizes on cooling, exactly as in the case of ordinary stearin. Full information on this, and the acid prepared from it, will be found at page 410, vol. i.

Palm Oil.—This very important fatty oil is procured from the fruit of a species of palm—*avouira elais* or *elais guineensis*—cultivated on the west coast of Africa, and in tropical America. The fruit of the palm is about the size of a pigeon's egg, and of a deep orange yellow color. It consists of a hard stone, within which is the seed, and surrounding the nut is a fibrous, oily, yellow sarcocarp, or fleshy integument, from which, by boiling in water, the oil is separated, rises to the surface, and may easily be collected. Fresh palm oil has an orange-yellow tint, a sweetish taste, and possesses an odor somewhat resembling that of violets or orris root. It has the consistency of butter or lard, is lighter than water, and, by exposure to the air, quickly becomes rancid, and of a paler hue. Its melting point is variable, ranging from 76° to 95°, and is still further heightened by age. It is slightly soluble in cold, more readily in boiling alcohol, but is deposited from the latter on cooling. In ether, it dissolves in all proportions. Palm oil was once considered of no importance in the arts and manufactures. At the present time it is exported from one port on the

African coast to the amount of upwards of twenty thousand tons annually, in exchange for foreign produce; and the annual consumption of palm oil in this country is upwards of twenty-five thousand tons, which are imported in exchange for goods of British manufacture. As it occurs in commerce, palm oil is in a state of rancidity, containing fatty acids in their free state, instead of in combination with oxide of glyceryl. The characteristic orange color of this oil is to be attributed to the spontaneous decomposition of a peculiar principle of the palm, always associated with the oil. The various processes for the destruction of this principle have been referred to in the article CANDLE, and will be alluded to also in connection with the manufacture of soap. Palm oil is composed, according to STENHOUSE and FRÉMY, of margarin, olein, a peculiar fat named *palmitin*, and coloring matter. In addition to these, there are found in commercial palm oil, oleic, palmitic, and sebacic acids in the free state, and also free glycerin. The principal use of palm oil is, after admixture with other oils, in the production of soap and candles. In soap-making, the oil is used both bleached and as imported, according to the kind of soap required; in the candle manufacture, the solid constituent only is used, and is hardened by the addition of wax. In Africa, palm oil is employed by the natives as a kind of butter. In this country, it is occasionally used by way of friction in cases of bruises and sprains.

Palmitin.—This solid fat constitutes about two-thirds of the weight of palm oil. It may be obtained tolerably pure and in large quantities, by pressing palm oil at a temperature of from 50° to 54°, and repeating the operation at about 75°. As thus procured, it appears as a wax-like mass, and is used in the manufacture of a variety of stearin candles, whilst the yellow fluid oil is saponified. It is obtained pure by washing the residue of the second pressure with hot alcohol, dissolving it in hot ether, and crystallizing repeatedly till the melting point becomes constant. Palmitin is insoluble in water, and only very sparingly soluble in boiling absolute alcohol, but very readily dissolves in ether. It fuses at 118°, and congeals on cooling into a friable mass similar to wax. Besides palm oil, palmitin is contained in bees-wax, in cocoa nut oil, and, according to HEINTZ, also in human fat. STENHOUSE represents palmitin by the formula, $C_{35} H_{70} O_4$, and as being composed of palmitic acid and oxide of glyceryl.

Butter of Cacao.—This substance is the fatty matter of the chocolate nut. The *theobroma cacao* is the tree producing this nut, and is grown extensively in Demerara, Berbice, the West Indies, and South America. There are numerous species of this tree, bearing different kinds of fruit, both as to form, size, and the number of seeds which they contain. They vary also in the yield of oil, not only according to the species whence obtained, but also to the mode of treatment after being gathered and removed from the fruit. The average size of good nuts is that of the sweet almond, but rather more thick. Those from Caracas or New Granada, are especially remarkable for the large proportion of fatty matter they contain. Cocoa and chocolate are preparations of the nut of this tree, produced by roasting and grinding, and sometimes with

the addition of various other ingredients, as sugar, starch, gum, treacle, arrowroot, *et cetera*. LAMPADIUS analysed the kernel of the cacao nut, with the following results:—

	Per cent.
Fat oil,.....	53.10
Azotized substances,	16.70
Starch,.....	10.91
Gum,.....	7.75
Coloring matter,	2.01
Woody fibre,.....	0.90
Water,.....	5.28
Ash,.....	2.00
Loss,.....	1.35
	100.00

The chocolate nut also contains an alkaloid, discovered by WOSKRESENSKY, and termed *theobromine*. It is strikingly analogous to *caffeine*, and especially remarkable for the large quantity of nitrogen it contains, amounting to 35.4 per cent. It is white, pulverulent, and of a bitter taste, and is nearly insoluble in water, alcohol, or ether.

Butter of cacao is obtained from the powdered kernels after being mixed with ten times their weight of boiling water, by expression in canvas bags, between heated iron plates. One pound of cacao yields from five to six ounces of oil. It is purified by long boiling with water, or on the small scale by boiling alcohol. The crude oil is yellowish and has the smell and taste of the nut. In the pure state it is colorless, inodorous, and tasteless. It is not liable to become rancid, and hence the great value of the nut as an article of diet. Its consistence is about that of tallow and its flavour rather agreeable. Its specific gravity is 0.91; its melting point about 120°. It is for the most part a crystalline combination of olein and stearin, fusing at about 85°. Cacao butter is readily soluble in hot alcohol, but is deposited on cooling. Ether also dissolves it. It may be employed in the manufacture of soap and candles. Cacao butter soda-soap is an agreeable toilet article for persons troubled with a rough skin or chopped hands. From its little liability to become rancid, cacao butter is peculiarly adapted to the preparation of such ointments as are to be kept for a length of time.

Laurel Oil.—This oil, termed also *oil of bays*, is imported from Trieste. It is procured from either the fresh or dried berries of the sweet bay—*laurus nobilis*. This plant is cultivated in the South of Europe, and bears a fruit of a bluish-black color, oval, and about the size of a small cherry. According to the analysis of BONASTRE, laurel berries have the following composition:—

	Per cent.
Volatile oil,.....	0.8
Laurin,.....	1.0
Fixed oil,.....	12.8
Stearin,.....	7.1
Resin,.....	1.6
Uncrystallizable sugar,	0.4
Gummy extractive,.....	17.2
Bassorin,.....	6.4
Starch,.....	25.9
Lignin,.....	18.8
Soluble albumen,.....	traces
Acid,.....	0.1
Water,.....	6.4
Salts,.....	1.5
	100.0

Laurel oil is obtained from the berries by boiling and by expression. According to DUHAMEL, the berries are bruised in a mortar, boiled for three hours in water, and then pressed in a canvas bag. The oil exudes with the decoction, and when cold, floats on the surface. The dried berries are steamed until thoroughly soaked, and then quickly pressed between heated iron plates. By the latter process they yield one-fifth of their weight of oil.

Laurel oil is of a greenish color, of the consistency of butter, and of a peculiar and characteristic smell. It melts at about 100°. It is partially soluble in alcohol, and completely so in ether. It consists for the most part of a peculiar variety of stearin, named *lauro-stearin*; the residue is a green liquid fat, probably olein. Laurel oil is saponifiable. It is occasionally employed in medicine as a stimulating liniment in sprains and bruises, and in paralysis. Its principal use, however, is in veterinary medicine.

Piney Tallow.—This fat is obtained from the seed of the *vateria indica*, a tree which is extensively grown on the coast of Malabar. The fat is not well-known in this country. A sample of it was shown in the Great Exhibition, and attracted much attention. To obtain it the seeds are boiled with water for some time, and on cooling, the concrete fat is removed. According to BABINGTON, its ultimate constituents are 77 of carbon, 12.3 of hydrogen, and 10.7 of oxygen. It is a white solid oil, fusible at 97°. It forms excellent material for soap and candles. Its great advantage over some other oils is, that the candles made of it do not give out suffocating acrid vapors when extinguished.

Butter of Nutmegs.—The fruit of the *myristica moschata* by expression yields this oil—known also as oil of mace. The nutmeg-tree grows to a height of twenty to twenty-five feet, and in appearance resembles a pear-tree. It is cultivated in the Moluccas, and in the East and West Indies. Several varieties of nutmegs are met with in commerce. Their principal consumption is for dietetical purposes. BONASTRE's analysis of these nuts is as follows:—

	Per cent.
Volatile oil,.....	6.0
Liquid fat,.....	7.6
Solid fat,.....	24.0
Acid,.....	0.8
Starch,.....	2.4
Gum,.....	1.2
Lignin,.....	54.0
Loss,.....	4.0
	100.0

The process employed in the extraction of the fixed oil is bruising the nut to a paste, inclosing the mass in a bag, and submitting it for some time to the action of steam. The whole is then placed between heated metal plates, and subjected to long-continued expression. The yield of nutmeg butter is about twelve per cent. of the weight of the nuts employed. It is imported in oblong cakes, covered with leaves, and weighing about twelve ounces. It is of a reddish-yellow color, firm consistence, and possesses the agreeable smell and taste of the nutmeg. According to SCHRADER, this oil consists of fifty-two per cent. of a liquid, and forty-four per cent. of a solid fat, with four of volatile oil. The solid portion consists for the most

part of a peculiar fat, named *myristin*, or *sericin*. The liquid oil is yellowish or brownish, soluble in cold alcohol, and in ether. Butter of nutmegs is readily saponifiable. It is an article also of the *materia medica*, and is sometimes employed as an unguent in cases of rheumatism and palsy. A spurious kind is said to be occasionally met with, composed of lard which has been boiled with powdered nutmegs, and flavored with sassafras. It may be readily known from the genuine butter by its insolubility in boiling alcohol.

Some other varieties of solid oil are imported in small quantity from the East Indies, but are not of sufficient importance to call for detailed notice; certain it is, however, that should accidental circumstances at any time occasion a scarcity of the oils now generally applied to manufacturing purposes, an almost inexhaustible supply of them might be obtained with little difficulty, and would probably replace the more common oils, without disadvantage either to the manufacturer or the consumer.

DRYING OILS.—The drying oils differ from those above described, by their peculiar behavior on exposure to the air, and also, as previously noticed, by the difference in their behavior under the influence of nitrous acid. The cause of the singular property of drying in contact with atmospheric air is not distinctly understood, but is usually attributed to some peculiarity in their olein.

LINSEED OIL.—This, the most important of the drying oils, is obtained by expression from the seeds of the common flax, *linum usitatissimum*. This plant is extensively cultivated in this, as well as other European countries, both for its fibre, used in producing thread, and for the oil obtained from its seeds. It is said to be a native of Britain, and yet it appears that flax-seed was not sown in England till about 1533, when it was directed to be sown for the production of flax for the manufacture of fishing nets. The seeds, commonly termed lintseed or linseed, are small, oblong, smooth, and pointed at one extremity. Externally, they are of a glossy brown color; and internally, yellowish white. Their taste is oily and mucilaginous. The mucilage, however, for the most part exists in the seed coats, and not in the nucleus, the latter being the richest in oil. The following analysis of linseed is by MEYER:—

	Per cent.
Fat oil,.....	11.265
Wax,.....	0.146
Acrid soft resin,.....	2.488
Resinous coloring matter,.....	0.550
Yellow extractive and tannin,.....	1.917
Sweet extractive, malic acid, and salts,.....	10.884
Gum,.....	6.154
Nitrogenous mucilage, acetic acid, and salts,.....	15.120
Starch, with salts,.....	1.480
Albumen,.....	2.782
Gluten,.....	2.932
Husk,.....	44.382
	100.000

According to GMELIN, the ashes contain oxide of copper. The proportion of fat oil contained in the seed is certainly much greater than that given in the preceding analysis; for, by expression in the cold, the yield of oil is from twenty-one to twenty-two per cent. of the seeds, and by the assistance of heat, combined

with a more powerful and long-continued pressure, as much as twenty-eight per cent. may be obtained. If a very pure oil be required, the process of cold expression must be pursued; a very good oil, however, may be obtained by a steam heat, not exceeding 20°. The ordinary method of getting rid of the large quantity of mucilage is by torrefaction, after which the seeds are bruised and submitted to pressure. The *marc* remaining after the expression of linseed oil is generally known as *oil cake*, and is an article of great importance to the agriculturist, being extensively employed, especially in the winter season, as food for cattle. By far the best oil cake is that from English seed. Independent of its use as an article of food, oil cake is an excellent medicine for cattle, as a preventive of constipation, besides which, it gives to the hide a *sweetness of coat* unattainable by other means. Foreign oil cake is certainly largely adulterated with the husks of other seeds, and many circumstances seem to lead to the conclusion, that the adulterant has been added previous to the expression of the seed. In this case, of course, foreign linseed oil must also contain spurious admixture, and will be less valuable as a drying oil than that expressed in this country. As regards oil cake, the consumer is assured that he will best consult his own interest by, in every case, submitting a sample to the inspection of a competent chemist previous to purchasing, for, in addition to the admixture of less nutritious seed coats, as bran, *et cetera*, many other positively injurious substances, as sawdust, clay, and other earthy matters, are frequently found in English, as well as foreign cake; and, in a case recently brought to the notice of the Editor, in which some sheep had died suddenly, the only cause to which death could be attributed was the enormous quantity of *sand* which he found in the stomach, and which the Editor considered could only have been introduced therein in admixture with the cake given as food.

The linseed meal—*farina lini*—of the Edinburgh Pharmacopœia, is powdered oil cake, and is frequently employed in this country as an emollient poultice. In this state also, it is often adulterated with bran, sawdust, *et cetera*. NORMANDY gives as a test of the genuineness of linseed meal, that when treated with ether it should yield fifty-three per cent. of oil. This, however, is manifestly a mistake. Linseed itself contains less than thirty per cent. of oil, of which, in most cases, twenty-five are extracted by expression, so that it will rarely happen that more than five or six per cent. at the utmost can be present in official linseed meal. Some medical practitioners prefer what they suppose to be simply powdered linseed, but which, in reality, is powdered oil cake, subsequently mixed with a greater or less quantity of oil. In this case, of course, a larger proportion of oil may be found on examination, but it by no means follows that meal containing less than fifty-three per cent. of oil should be designated as spurious. But to return from this digression to the consideration of oil of linseed. If extracted by cold expression, when it is termed *cold drawn* linseed oil, it is paler colored, less odorous, and has less taste, than that obtained by the aid of heat. In the latter case, the oil is of an amber or brownish-yellow color, and

also more susceptible of rancidity than when cold drawn. The smell and taste of linseed oil is highly characteristic and peculiar to itself. Its specific gravity, according to SAUSSURE, is 0.9395 at 52°. It dissolves in five parts of boiling, and forty of cold alcohol, and in about one and a half times its volume of ether. According to SACC it consists of one equivalent of margarate of glyceryl, and ten equivalents of a peculiar fat, termed *linolein*. If cooled down to about minus 20°, it may be kept some time without suffering any important change. After the expiration of a longer or shorter period, however, dependent upon the precise temperature, it becomes darker-colored and deposits a portion of its solid constituent along with coloring matter; at a few degrees lower, it becomes entirely converted into a concrete yellow mass. Linseed oil may be completely decolorized by the action upon it of protosulphate of iron in conjunction with sunlight. A solution of two pounds of the salt in two and a half pounds of water, is poured into a flask containing two pounds of linseed oil, and the whole is submitted to sunlight for some weeks with frequent agitation. The oil becomes limpid and colorless, and may be drawn off by a siphon or otherwise.

Linseed oil is most largely used in the manufacture of paints and varnishes. Its drying properties, as previously remarked, are much increased by boiling with a small quantity of litharge, or of peroxide of manganese. It is used also in the preparation of printers' ink, in the preparation of black enamel for leather, and in the varnishing of oiled silk. For the finer purposes of art, it is purified and decolorized as above directed. In white-lead works, linseed oil is bleached by sulphuric acid, and the small portion of acid always remaining in the oil after this operation, has the good effect—by converting into sulphate any hydrate of lead that may be present in the white-lead with which it is ground—of preventing the production of the yellow higher oxide when the paint is exposed to the air. A method of purification especially to be recommended when the oil is to be used in the preparation of varnish, is to triturate the oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to light, and with frequent agitation, the mucus and parenchymatous matters deposit with the sulphate of lead, and leave the oil perfectly clear. The oil will then, after some time, become quite white. The precipitated matters form a compact membrane above the salt of lead, and become so hard that the supernatant clarified oil may be poured off. The lead sediment may again be used for the same purpose. Varnish so prepared is especially valuable in those cases where the presence of a salt of lead would be injurious—as for instance with lake colors, with sulphide of cadmium, and other pigments containing sulphur. When long kept in a bottle only half filled with it, the linseed oil becomes more thick, and does not dry as well as before. By this treatment, however, it acquires the property of comparatively ready solubility in alcohol, and is therefore added with advantage to several spirit varnishes to diminish their brittleness.

The substance known as *caoutchouc of oils* is obtained from linseed oil as follows:—The oil is exposed for some time, as in the preparation of printers' ink, to a

high temperature, when it becomes converted into a dark tenacious mass. If this be boiled for some hours with dilute nitric acid, it acquires a thick consistency, and becomes hard on exposure to the air, but softens again by the heat of boiling water, and again hardens to a consistency resembling that of caoutchouc, for which, indeed, it may in some instances be substituted. This singular body is soluble in oil of turpentine, in bisulphide of carbon, and in dilute alkaline solutions; from the latter it is thrown down unaltered on the addition of an acid. Other drying oils, beside linseed, yield a similar substance, though not so abundantly. Linseed oil is frequently adulterated with resin or colophony. This may be detected by digesting the oil with alcohol, decanting the latter, and adding acetate of lead, when the appearance of a white precipitate is indicative of this falsification.

By digestion with alkalies or with metallic oxides, linseed oil is easily saponified. The proportion of oxide of glyceryl in this oil is greater than in most other oils, and hence, by far the most advantageous method of preparing glycerin, is by moderately heating this oil with oxide of lead.

Walnut Oil.—This drying oil is derived from the kernels of the *juglans regia*, or walnuts. The nuts are freed from their ligneous shells, inclosed in bags, and submitted either to cold or hot pressure. That prepared by hot pressure has a peculiar taste and smell, the latter being especially recognizable during its combustion. The oil obtained by cold expression is pale, yellowish-green or almost colorless, has an agreeable odor and taste and a sirupy consistency. If colored, it loses the greenish hue after some time. It congeals at about the same temperature as linseed oil, and possesses the property of drying by exposure in even a higher degree than the latter. In drying, it absorbs fifteen and a half times its volume of oxygen, at the same time giving off carbonic acid to the amount of two-fifteenths of the oxygen absorbed. The hot-pressed oil is usually high colored, has a powerful odor, and contains large quantities of mucilage. The specific gravity of walnut oil, according to SAUSSURE, is 0.9283 at 52°; 0.9194 at 76°; and 0.874 at 200°.

It is principally used in painting, and by varnishers, and being comparatively clear and colorless, is especially valuable as the vehicle for lake white, and other pigments, when it is desired to preserve the brilliancy of their tints. When fresh, it is occasionally employed for culinary purposes, but when rancid, it is purgative. Sometimes also it is used as a source of light.

Poppy Oil.—The seeds of the poppy—*papaver somniferum*—yield this oil by expression. This plant appears to grow wild in some parts of Great Britain. It is extensively cultivated in Hindostan, Persia, Asia Minor, and Egypt, on account of the opium obtained from it. In Europe, the poppy is cultivated for the capsules or *poppy heads*, either as medicinal agents, or for the oil obtained from their seeds. No analysis of the seeds appears to have been made. Poppy oil is whitish-yellow, inodorous, with an agreeable almond flavor; it much resembles olive oil, for which, as already noticed, it is sometimes used as an adulterant. When pure, it is much less viscous than most oils, and remains liquid

even to 0°. Its specific gravity is 0.9249 at 60°. It is soluble in about twenty-five parts of cold, and six of boiling alcohol, and in ether in all proportions. It is used as a means of detecting the presence of spirit of turpentine in essential oil. In France and on the Continent, it is frequently used for culinary purposes, as a substitute for olive oil. When its drying properties are increased by treatment with litharge, it is frequently used in painting. It is employed also for illuminating purposes.

Hemp-seed Oil.—This oil is extracted from the seeds of common hemp—*cannabis sativa*. The plant grows wild in Persia, Caucasus, and the North of India. It is cultivated in various other countries. The seeds are small, ash-colored, shining, nut-like bodies. They are employed for feeding cage birds, and, according to BURNETT, possess the singular property of changing the color of the plumage of bullfinches and goldfinches from red and yellow to black, if the birds are fed on the seeds for too long a time, or in too large a quantity. The following is their composition as obtained by BUCHOLZ :—

	Per cent.
Fixed oil,.....	19.10
Resin,.....	1.60
Sugar and extractive,.....	1.60
Gummy extract,.....	9.00
Soluble albumen,.....	24.70
Ligneous fibre,.....	5.00
Husk,.....	38.30
Loss,.....	0.70
	100.0

The oil is extracted principally in Russia. The yield is stated by PEREIRA to amount to twenty-five per cent. of the seeds. This, however, is only in extreme cases, the quantity usually obtained rarely exceeding from fifteen to twenty per cent. The oil has a greenish-yellow tinge, a disagreeable smell, and a mawkish taste. The specific gravity at 52° is 0.9276; at 5° it becomes thicker, and at minus 16° it is solid. It is readily soluble in boiling alcohol, and in about thirty parts of this spirit when cold. It is used in painting, and in the preparation of a soft soap. It is occasionally employed in Russia as a source of light, but is apt to form a viscid adherent varnish, which impedes its passage through the lamp.

CASTOR OIL.—*Huile de ricin*, French; *ricinusöl*, German; *oleum ricini*, Latin. This oil is extracted from the seeds of the *palma christi*, or common ricinus, which is cultivated in the East and West Indies, and in the United States of America.

The plant yielding it was known in the most ancient times; indeed many suppose the plant called the *gourd*, mentioned in JONAH, to be the same as that now recognized as the castor oil plant. The Egyptians were certainly acquainted with it, as CAILLAUD discovered its seeds in some Egyptian sarcophagi, conjectured to have been upwards of four thousand years old. It was known to the ancient Greeks, and is alluded to by HERODOTUS and HIPPOCRATES, the latter of whom employed its root in medicine. The Latins gave it the name of *ricinus*, whence its botanical appellation. In this country the *ricinus communis* is an annual, and seldom exceeds four feet in height. In other countries

it is said to be perennial, arborescent, growing to the height of fifteen or twenty feet, and of many years' duration. It has large vine-shaped leaves, green spikes of flowers, and rough capsules containing ovate shining black seeds, spotted with grey. The following analysis of the seeds of this plant is by GEIGER :—

	Per cent.
Seed coats,.....	{ Resin and extractive, 1.91
	{ Brown gum,..... 1.91
	{ Ligneous fibre,..... 29.00
	{ Fatty oil,..... 45.19
Nuclei of the seed,...	{ Gum,..... 2.40
	{ Albumen,..... 9.50
	{ Ligneous fibre and starch, 29.00
Moisture,.....	7.00
	100.00

In opposition to GEIGER's results, BUCHANAN states that the residue freed from oil consists for the greater part of emulsion, is not colored blue by iodine, and instead of starch contains sugar; for an emulsion of castor seeds, mixed with yeast, undergoes the alcoholic fermentation at a low temperature.

Extraction of the Oil.—Various methods have been adopted for the preparation of castor oil. The expression of the seeds in the cold, though a more tedious process, yields a much superior oil to that obtained when the pressure is assisted by heat. Previous to expression the seeds should be deprived of the outer coating or shell, when they yield an oil nearly colorless, or with a slight yellow tint.

According to SOUBEIRAN, BUSSY, and LECANU, all processes in which heat is employed are objectionable, as the oil is rendered acrid from the liberation of fatty acids. In the American Dispensatory, on the contrary, the application of heat is stated to improve the oil by volatilizing a disagreeable acrid principle; and hence the almost universal practice in America is first to submit the seeds to gentle torrefaction, the heat being insufficient to scorch or decompose them. They are then introduced into a powerful screw press, and submitted to pressure. A whitish oily liquid exudes, which is boiled with a considerable quantity of water in iron boilers, and the impurities skimmed off as they rise to the surface. The coagulated albumen forms a layer between the oil and the water, and the starch and gum are retained in solution in the water. The clear oil is next drawn off and boiled with a small quantity of water until aqueous vapor ceases to rise, and till a small portion of the liquid taken out in a phial preserves a perfect transparency on cooling. The effect of the latter operation is to clarify the oil, and render it less irritating, by driving off volatile acrid matter, the quantity of which is doubtless much increased by the process of torrefaction to which the seeds are subjected. The process of cold expression, purification by subsidence and decantation, is also employed in America, though on a much less extensive scale.

In England castor oil is expressed by BRAMAH's hydraulic press, or by the common screw press, in a room artificially heated. It is purified by rest, decantation, and filtration, and bleached by exposure to light on the tops of warehouses. In Calcutta, according to PEREIRA, the process is as follows :—The fruit is shelled by women; the seeds are bruised between rollers, then placed in hempen cloths, and pressed in

the ordinary screw or hydraulic press. The oil thus procured is subsequently heated to 212° with water, in a tin boiler, by which the albumen is coagulated, and, with the mucilage, separates as a scum. The oil is then passed through flannel, and run into square tin cases. The best oil of this variety is sold in London as *cold-drawn castor oil*. According to AINSLIE castor oil is obtained in the East Indies also by decoction, and this process is likewise pursued in the West Indies.

The process of FIGUIER is now followed on the Continent of Europe on a considerable scale. It consists in mixing the seeds, first deprived of their outer coating and bruised into a paste, with alcohol. This mixture is inclosed in canvas bags, and submitted to pressure. Part of the alcohol is recovered by distillation of the mixture of oil and spirit; the residue is then mixed with a large quantity of water, when the oil rises to the surface, and is drawn off. It is again heated to remove traces of moisture and then filtered. This process is more expensive than those previously given, and the product is inferior.

After its arrival in this country, foreign castor oil is filtered, and bleached by exposure to solar light on the tops of warehouses. Of the several varieties met with in commerce, the East Indian castor oil is the most abundant. It is an oil, in every respect, of good quality, but inferior to English cold-drawn oil. American oil rarely finds its way into this country. It has a less acrid taste than the East Indian variety, but is objected to because at a low temperature it congeals quickly, deposits a white substance termed margaritin, and becomes opaque.

Properties.—When very pure, castor oil is a thickish, viscid fluid of a bright yellow hue, with a slightly nauseous smell, and a mild, somewhat sweetish taste, succeeded by a slight sense of acrimony. The oil of commerce is, however, frequently of a greenish, and occasionally of a brownish color, with a hot acrid taste. Its specific gravity is, according to SAUSSURE, 0.9801 at 49° ; 0.9699 at 52° ; and 0.9575 at 76° ; and is, consequently, heavier than most other fixed oils. Its composition and properties are essentially different from those of other oils. It is soluble in absolute alcohol in all proportions. Spirit of wine, of specific gravity 0.8425, dissolves about three-fifths of its weight. It is also readily soluble in ether. This oil forms the connecting link between the siccative and non-drying oils. By long exposure to the air it becomes rancid, but gradually hardens without becoming opaque. It retains its fluidity even at a temperature of 0° . At a lower degree, it congeals into a transparent yellowish mass. The action of heat upon castor oil has been particularly investigated by BUSSY and LECANU. When heated in a retort, so as to distil over about one-third, there remains a substance, solid at ordinary temperatures, having the appearance of a yellowish porous body resembling caoutchouc. It requires a high temperature for its decomposition, and is easily inflammable, without undergoing fusion. It is insoluble in water, alcohol, ether, and in the fixed and volatile oils. The alkalis convert it into a species of soluble soap. The products of distillation are a little gas, and a liquid containing acetic, *ricinic*, *ricinoleic*, and *margaritic* acids, and an

odorous, colorless, volatile oil, which crystallizes on cooling.

Adulteration.—Castor oil is said to be frequently adulterated with other fixed oils, and especially with lard oil. For the detection of this falsification, the Edinburgh Pharmacopœia directs that it be examined as to its solubility in alcohol, which dissolves its own volume of castor oil. This test, however, is of no practical value, as the solubility of other fixed oils is greatly increased by admixture with castor oil, and even a third of its weight of another oil may be present, and still a perfect solution be obtained with an equal volume of alcohol. Of the different kinds of genuine oil, English is, according to PEREIRA, the most soluble, and East Indian, the least soluble, in rectified spirit. A far more dangerous fraud than the above, is the occasional one of adding a small proportion of *croton* oil, with the view of increasing its purgative activity, and this, unfortunately, is not of easy detection.

Physiological Effects.—On animals generally, castor oil acts as a laxative or gentle purgative. Its great advantage over other purgatives is the rapidity of its action—usually not more than two or three hours after its exhibition. It not unfrequently occasions nausea, or even vomiting, but this effect is rather to be attributed to its disgusting flavor than to any positively emetic property. Some continental writers have stated it to be very unequal in its action, sometimes operating with considerable violence, and at others with great mildness. This is not found to be the case in this country, though PEREIRA readily admits that a difference in the mode of its preparation may materially affect its aperient property. As obtained by boiling, it is deeper colored, more acrid, and more susceptible of rancidity, than the cold drawn oil, and at the same time is undoubtedly possessed of more active properties. The bleaching process, although it removes color and taste, is also injurious to the oil, often rendering it almost inactive; and therefore, medicinally, the pale straw-colored oil—not absolutely tasteless, and with a certain degree of smell—is to be preferred. Castor oil is employed principally in cases of inflammation of the stomach, in spasmodic affections of the bowels, especially in lead colic, in other internal inflammatory and spasmodic diseases, and as a purgative in habitual costiveness. The dose is from two drams to two ounces, and it may be taken swimming on the surface of milk or coffee, warmed and beaten up with the yolk of egg or mucilage of tragacanth, or with the addition of a little orange wine. The vessel from which it is taken should be previously warmed, and moistened with water or other liquid. The nauseous clammy taste is most easily removed by masticating a crust of bread or a little oatmeal.

Statistics.—The quantity of castor oil imported annually during a period of seven years was as follows:—

	Pounds.
1843,.....	1,051,792
1844,.....	1,223,264
1845,.....	1,801,632
1846,.....	1,487,168
1847,.....	451,584
1848,.....	513,856
1849,.....	1,084,272

Grape-seed Oil.—This oil, called also *oil of wine-stones*, is extracted by pressure from the seeds of the grape—*vitis vinifera*. The yield is sometimes to the amount of twenty-two per cent. Its color is at first pale-yellow, but after some time it assumes a darker tint, and becomes at the same time viscous, thick, and rancid. When fresh and pure it has little odor, and a very mild taste, and hence is useful for culinary purposes. Its specific gravity is 0.9202 at 59°. It is used principally as an article of diet.

Cotton-seed Oil.—The seeds of the cotton plant—*gossypium barbadense*—yield an oil which may at no distant period become an important article of commerce. The plant is grown principally in the Southern part of the United States of America, but also in India, China, and other warm climates. Owing to the enormous quantity of cotton annually produced, there must always be an abundance of seed, which it is desirable to convert to some useful purpose. The subject has long engaged the attention of parties interested in the promotion of the useful arts. Even so far back as 1785, the Society for the Encouragement of Arts and Commerce offered a prize for the manufacture of oil from cotton-seed on the large scale, but no successful claimant has yet appeared. It has, however, been extracted to a certain extent in Egypt, America, and India. The great difficulty in the way of its introduction appears to have been that of effecting its purification. Of late years, this oil has attracted a greater share of attention, and means have been devised of purifying it, and removing the dark color which it possesses in the raw state. Even now, however, large quantities of cotton-seed are annually destroyed, as far more is produced than is required for the crop of the succeeding year, and this has hitherto, for the most part, been thrown away as useless, or in some cases applied as a manure; still it is now in some solitary instances collected and exported for the manufacture of oil and oil-cake. A sample of the oil and expressed cake were shown in the Great Exhibition by R. BURN of Edinburgh, and of raw and bleached oil by DE GÉMINY of Marseilles, to whom prize medals were awarded. The latter was from Egyptian seed.

Croton Oil.—This acrid oil is extracted from the seeds of the *croton tiglium*, and is imported from Madras and Bombay. In size and shape these seeds much resemble castor-seeds. They have no smell; their taste is at first mild and oleaginous, afterwards hot and acrid. Besides BRANDE, PELLETIER, and CAVENTOU, Dr. NIMMO also examined them. The result of BRANDE's analysis is subjoined:—

Volatile oil,	traces.
Fixed oil, with crotonic acid and crotonin,	17.00
Crotonates and coloring matter,	0.32
Brownish-yellow resin,	1.00
Stearin and wax,	0.65
Extractive, sugar and malates of potassa and lime,	2.05
Starch, with phosphate of lime and magnesia,	5.71
Gum and gummosin,	10.17
Albumen,	1.01
Gluten,	2.00
Seed coats and ligneous fibre,	39.00
Water,	22.09
	100.00

Croton oil is extracted by expression from its seeds. That of the shops is very impure, being a mixture of the oil with other constituents of the seed. DUMAS gives the process for obtaining it as follows:—The crushed seeds are submitted to the press, and the oil that flows out is allowed to stand from twelve to fifteen days to deposit; it is then drawn off and filtered. The expressed cake is treated with twice its weight of rectified spirit, and heated in the salt-water bath. The alcohol dissolves a large quantity of the oil remaining in the *marc*, and is separated from it by evaporation. Sometimes, the seed, freed from their husks, are pulverized and treated at once with spirit; the mixture is heated in the salt-water bath, allowed to cool, inclosed in a bag, and pressed. The alcohol is afterwards removed from the oil by distillation. Croton oil is of a brownish-yellow color, has a very disagreeable characteristic odor, and a strongly acrid taste. It is soluble in alcohol and in ether. In doses of one drop, it operates on man as a violent purgative. It appears to consist of a mixture of a fatty oil with another very acrid substance, very soluble in cold alcohol, and containing a large quantity of crotonic acid, both free and in combination with oxide of glyceryl, and with magnesia. The combination of the acid with the latter base was supposed by BRANDE to be a peculiar alkaloid.

ANIMAL OILS.—It is unnecessary again to allude to the origin and formation of animal fats, the various theories concerning which have been previously fully detailed and discussed. It will be sufficient to say here that by far the greatest proportion of the fat of animals is the result of the deoxidation of the amylaceous principles of vegetal food, and that the fat originally formed and existing in vegetal food also accumulates, undergoing considerable modification in the animal body. Hence the fat of the *herbivora* is that which most closely resembles the fat of vegetables; and the fat of the *carnivora*, having undergone a still further modification in the animal body, is that which most widely differs from vegetal oils. It has also been already noticed in what part of the animal fat is for the most part secreted. It is contained in what is termed adipose membrane, and may be obtained by exposure to a sufficiently high temperature to liquefy the fat, and tear asunder its including cells. To assist the operation, the fat should be divided into small pieces, so as to allow the more uniform influence of heat; and it is important that the melting process be performed before any putrefaction of the membrane, or of other fibrous and fleshy accidentally adhering matters, has taken place. The fat is usually melted in an open copper exposed to the direct action of the fire, and after fusing for a considerable time, the membranous matters collect at the surface. These are removed, and after having been pressed to remove adhering oil, they form *greaves*, sometimes termed also *cracklings*, from their crispy nature, and in the form of flat cakes are sold as food for dogs, as manure, and for the production of yellow prussiate of potassa. The melted fat is passed through a sieve into another copper, where it is washed with a quantity of boiling water. The impurities settle down with the water, and the fat is drawn off into tubs and allowed to cool.

In France, and on the Continent, another method is adopted for the separation of fatty matters from the cells or tissues in which they are confined. The fatty matter is placed in contact with very dilute sulphuric acid for a few days, after which the fat is removed from the macerating vessel, and with the addition of about half its weight of a little stronger acid, put into a suitable wooden vessel, and subjected to a jet of steam, which soon causes the whole to boil. Under the influence of heat and of the dilute acid, the albuminous tissue which envelopes the fatty matter is rapidly destroyed, and the latter set free floats on the surface of the boiling water; after which the jet of steam is stopped, and the liquid fat is drawn off into a proper receiver. The addition of a little strong acid again prepares the melting-vessels to receive a new charge of the digested fat, which may also be drawn off after a short time. Larger pans are required in this operation than in the former, to perform the same amount of work; but the work is done more quickly. The animal matters remaining in the pan can be used as manure, or, after mixing with a little sawdust, as fuel. By this method, also, the operation of fat-melting is rendered perfectly safe, and the highly disagreeable odor characterizing the vicinity of establishments devoted to this purpose, is entirely removed.

The variable consistency, color, and odor of the different fats depends for the most part upon the kind of animal whence obtained, its climate, and its food; but male animals generally yield a firmer fat than female. A good quality of fat can come only from a healthy animal, and winter fat is better than that taken in summer. According to WATT, the fat of an animal is more solid the further it exists from the surface of the body; and the delicacy of the cellular tissue enveloping the fat is in proportion to the consistency of the latter. He is of opinion also that the fat of animals in temperate and tropical climes is much more firm than that from those of cold regions. This statement, however, requires additional experience and observations before it can be received as a law of the animal economy.

Fats always melt at a lower temperature than the solid acid which they yield by saponification; but the melting point varies with the part of the animal whence extracted. They are generally tasteless and neutral when fresh, but acidify and become rancid by exposure to air. Their specific gravity is below that of water, and they are all more or less fusible. Alcohol partially dissolves them, but they are wholly insoluble in water. In carnivorous animals the fat is usually soft and rank-flavored; in the ruminants nearly inodorous. In well-fed young animals it is generally white and abundant, and in the old, yellowish and more scanty.

The following is a list of the principal animal fats, with the fusing point of each:—

	Fusing point.
Badger fat,.....	86·0°
Beef suet,.....	98·5
Calf suet,.....	136·8
Camel suet,.....	131·0
Cows' butter,.....	79·7
Dog fat,.....	79·75
Elephant fat,.....	82·0
Fox fat,.....	129·0
Hare fat,.....	117·5
Hogs' lard,.....	80·5

	Fusing point.
Horse grease,.....	140·0
Human fat,.....	77·0
Goat fat,.....	"
Stearin of human fat,.....	120·0
" mutton suet,.....	109·0
" beef suet,.....	111·0
" hogs' lard,.....	109·0
Neat's-foot oil,.....	liquid below 32·0

TALLOW.—Under this name is included the fat of oxen, sheep, goats, deer, and some other animals. They all consist for the most part of stearin, with a little olein, while some also contain certain quantities of a particular ingredient which communicates to the fat characteristic properties. As far as their application is concerned, they are alike in properties. As a source of light, tallow is more or less valuable according to its greater or less degree of solidity; and is found from experience to be more solid, and consequently more valuable, in animals fed upon dry, ripe fodder, than in such as are supplied with green food or grains. Hence the tallow imported from Russia, where the animals are fed for eight months upon dry fodder, is generally superior to that produced at home.

The process for the separation of tallow from the membrane and tissue in which it is included in the animal body, is the same as that given for preparing the animal fats in general. The methods of purification and clarification are modified according to the purpose to which it is to be applied, and the greater or less degree of cleanliness, or freedom from foreign matters, of the fat itself. To separate the solid and liquid constituents of tallow, it is melted, and constantly stirred whilst in the act of congelation. It is then pressed in woollen bags, at a temperature of about 95°; the olein which is thus pressed out still retains much stearin, but by repeatedly pressing in a similar manner, lowering the temperature each time by a few degrees, an olein is obtained, fluid at 32°, and the stearin is hard and granular. The hardening and whitening of tallow may be accomplished by other means than pressing, a description of which will be found under the article CANDLE. Also, for farther information upon this and other of the following fats, see vol. i., page 413 *et sequitur*.

Tallow Oil.—The liquid fat separated from tallow by pressure is known under this name. The best method of obtaining it consists, according to MORFIT, in steaming the tallow in wooden tubs for several hours, drawing off the upper clear portion after sufficient repose for subsidence of foreign matters, and gradually cooling in large tubs between 70° and 80°. These tubs are provided with a cullendered diaphragm, about six inches from the bottom, and which should be covered with coarse flannel cloth. During repose, the solid portion of the tallow separates in granules from the superstratum of fluid olein, and deposits upon the diaphragm, thus allowing the liquid olein to percolate upon the opening of the cock at the bottom, and be drawn off into receivers. The solid residue, upon being subjected to pressure in Russian canvas bags, yields more olein, and itself remains hard and white. Tallow oil is thick and mushy, and admirably suited to the manufacture of the finer kinds of soap.

Beef Tallow.—The fat of oxen is firm and brittle,

has a yellowish-white color, and a slight but peculiar odor. It melts at a temperature of 100° , is insoluble in water, but soluble in forty parts of boiling alcohol of specific gravity 0.821. It consists of olein and stearin, in the proportion of three parts of the latter to one of the former. The solid constituent or stearin is white, granular, and crystalline. It melts at 111° , and again solidifies at 102° . It has about the same translucency as white wax. Its feel is not greasy, and in burning it gives a light similar to that of wax. It dissolves in absolute alcohol, to the amount of fifteen and a half parts in a hundred. The olein of beef fat is colorless, with only a slight odor. Its specific gravity is 0.913. One hundred and twenty-three parts are soluble in a hundred of absolute alcohol, at the temperature of 167° . Beef tallow is used principally in the manufacture of soap and candles.

Mutton Suet.—This fat is similar to the preceding, but is whiter. It is very firm and brittle, has scarcely any smell, is completely insoluble in water, slightly soluble in alcohol, and melts at temperatures between 100° and 106° . The solid portion of this fat, which amounts to seventy-four per cent., consists, according to HEINTZ, of stearin, margarin, and palmitin. It is white and lustreless. It begins to solidify at 99.5° , is translucent, and partially soluble in alcohol. The olein of mutton suet is colorless, has a slight odor of the flesh of the animal, and a specific gravity of 0.913. Eighty parts of it are dissolved by one hundred of absolute alcohol, at the temperature of 167° . In addition to these ingredients, mutton suet probably contains *hircin*.

Goats' Fat.—This fat resembles that of the ox, but it has a disagreeable smell, arising from the presence of a peculiar oily matter, first discovered by CHEVREUL, and termed by him *hircin*. It is liquid, and is found in the olein when the fat of goats is separated into its solid and liquid constituents. It is composed of oxide of glyceryl, united to a peculiar acid named *hircic*. Although *hircin* has not yet been obtained pure, CHEVREUL prepared the acid into the constitution of which it enters. His process was by saponification, decomposition of the soap by tartaric or phosphoric acid, and distillation of the mixture of fatty acids, when *hircic* acid is found in the receiver under the form of a colorless volatile oil. It has a capreous and acetic odor, an acid reaction, is difficultly soluble in water, and easily so in alcohol. With the bases it forms salts, of which that of baryta is difficultly soluble.

Cows' Butter.—This fat is derived from the milk of the cow. The various methods of manufacture, *et cetera*, have been treated under a separate article, page 397, *et seq.* It may be purified from buttermilk, cheese, and other impurities, by melting it, when the foreign matters subside with the water, and the pure oil rises to the surface. The characteristic odor and flavor of butter are owing to the presence of a small quantity of several peculiar fats, named—*butyrin*, *caproin*, *caprylin*, and *caprin*. These fats are combinations of oxide of glyceryl with the volatile butyric, caproic, caprylic and capric acids. According to HEINTZ, the solid portion of butter contains, besides palmitic acid, another acid which he terms the *butic*, and gives the following formula: $\text{—C}_{40}\text{H}_{40}\text{O}_4 = \text{C}_{40}\text{H}_{39}\text{O}_3, \text{HO}$.

Hogs' Lard.—This fat is generally prepared from the adipose matter of the omentum and mesentery of the hog. It is white, and has very little odor. It melts at 100° , forming a transparent and nearly colorless fixed oil. According to SAUSSURE, its specific gravity is 0.9302 at 60° . One hundred parts of boiling alcohol dissolve nearly three parts of its olein. Exposed to the air for some time, it becomes gradually yellow-colored and rancid, acquires a powerful odor and an acid reaction. In this process a volatile fatty acid is developed, which CHEVREUL considers analogous to caproic acid. Hogs' lard consists essentially of olein, stearin, and margarin, and by saponification gives nine parts of glycerin and 94.65 of a mixture of the fatty acids. According to BRACONNOT, the proportion of olein is sixty-two, and of the solid constituents thirty-eight per cent. The solid portion is without smell, translucent, dry, and granular. It melts at 109.5° . On congealing, it assumes an imperfectly crystalline texture.

Lard Oil.—This fluid oil is prepared from lard in the same manner as is directed for tallow oil. It is considered much superior to sperm or olive oil for greasing wool, and, from its low price, is largely used. It is usually sufficiently white and clear for use, and should on no account be bleached by chemical means, as it is liable to retain enough of the bleaching agent to injure its quality, and render it inapplicable for many purposes.

Human Fat.—The fat of man has a similar consistency to hogs' lard. Its melting point seems to vary with the part whence it is extracted. It requires forty parts of hot alcohol of the specific gravity 0.821 for solution. On cooling, the alcoholic solution deposits stearin, which, after re-solution and deposition, and pressure in blotting paper, may be considered pure. This stearin crystallizes in a mass of small needles. It is colorless, has little lustre, and melts at 122° . One hundred parts of boiling anhydrous alcohol dissolve 21.5 of this stearin, but the greater part is again deposited on cooling. The olein of human fat is a colorless oil, which solidifies in needles at about 24° . Its specific gravity at 59° is 0.913. It has no smell, but a sweetish taste. Alcohol dissolves more than its own weight of this olein. By saponification, human fat yields 9.66 parts of glycerin, and 95.24 of margaric and oleic acids per cent.

Under the name of *adipocere*, FOURCROY described a peculiar fatty substance found in a cemetery at Paris, and supposed to have been partly formed during decomposition. CHEVREUL has shown that this matter is the original fat of the body, which has resisted putrefaction, and is partly in the state of fatty acid, and partly as ammonia soap, with traces of lime and magnesian soaps. This substance may often be found in the neighborhood of graveyards.

Neat's-foot Oil.—This oil is obtained from the feet of oxen; and as it remains liquid below 32° , and is in other respects a useful lubricant, is much employed to oil machinery. In America, according to MORFIT, it is extracted by the following process:—The feet, as collected from the slaughter-houses, are soaked in cold water to remove the blood, and, after removing the sinews, are placed perpendicularly in sufficient boiling

water to cover the hoofs. In about a quarter of an hour they are to be taken out, and the hoof separated by a suitable machine. The next step is to joint them with a knife, to sever the toes from the large bone. The latter is boiled with water by steam, while the former, which are more obstinate in yielding their fat, are boiled in the open pan with water previously used for the large bones. After the boiling, the liquid is left to repose, so that the oil may rise to the surface and be drawn off. The collected oil deposits after some time a thick stratum of dirty semifluid fat, from which the clear supernatant portion must be decanted.

This oil consists of olein, margarin, and stearin; it is white and fluid at ordinary temperatures, but congeals a few degrees below 32°. It is very frequently adulterated with horse oil, common lard oil, bone fat, some vegetal oils, and even with fish oils. The pure oil is not liable to change or rancidity, and is used as a lubricant, and is especially useful for machinery exposed in cold situations, as in the case of church clocks, *et cetera*, which require an oil not liable to become concrete.

FISH OILS.—Certain fish, especially the *cetacea*, yield a greasy fluid or oil, called or named according to the fish whence it is extracted. All fish oils contain certain peculiar animal matters, which impair their illuminating power, but do not injure them for the purposes of the soapmaker. They are extracted by melting the blubber, and the foreign matters are then partially separated by steaming the oil and allowing it to repose. Under the term, *train oil*, are included, whale, seal, cod, shark, and all oils obtained from fish of a like nature.

Whale Oil.—This well-known fish oil is obtained by boiling the blubber of the *Balena mysticetus*, or great northern whale. The pursuit of this whale forms an important branch of industry, as well as a nursery for British seamen. It was formerly found on the east shores of Greenland, but of late years in Davis' Straits and the interior of Baffin's Bay. The whale fishers merely cut out the blubber, pack it into casks, and carry it to the seaports to be melted out. The carriage gives rise to an incipient decomposition of the animal matters, and of the fluids attached to the blubber, which, although it aids the melting, occasions the formation of a peculiar fat, termed *phocenin*, which is the cause of the disgusting odor which always accompanies train oil. The cellular tissue of the blubber thus becomes so broken down that the oil runs off by itself, when the whole is put into casks with wirework bottoms, such as are used in the melting houses. The oil is afterwards heated to 212° that the impurities may the more easily separate, and after standing some time, the clear oil is decanted.

In train oil the impurity is not mucus, as in the vegetal oils, but animal gelatin or glue, and, besides this, volatile, stinking matters. Some clarifiers use a solution of tannin for purifying it, which forms with the gelatin insoluble flakes; others employ metallic salts, as sulphate of copper or acetate of lead, which act in a similar manner. The nauseous odor is most easily removed by bleaching-powder.—*Knapp*.

The color of whale oil is brown, and it has a disagreeable fishy smell. Its specific gravity at 68° is

0.927. When cooled to 32°, it deposits stearin, and the residual oil is soluble in less than its own weight of boiling absolute alcohol; the stearin is soluble in about twice its weight of this liquid. When the solution is cooled, it deposits first white brilliant crystals, and afterwards crystals tinged with yellow, and a thick brown liquor remains. When this stearin is saponified and the soap is decomposed by an acid, glycerin is obtained, and about forty per cent. of fatty acids, with a little *phocenic* acid in admixture.

Seal Oil.—The seal-fishery is by far the most important part of the trade of Newfoundland, the annual catch of the fish being little short of three quarters of a million. The principal seals captured are the *hood* and *harp* seal, of which the latter is the best and most productive. The first operation after landing and weighing is the skinning, or separation of the fat from the skin; after which the fat is cut off, and transferred to the seal-vat. The latter consists of what are termed the *crib* and the *pan*. The crib is a strong wooden erection, from twenty to thirty feet square, and twenty to twenty-five in height. It is firmly secured with iron clamps, and the interstices between the upright posts are filled in with small round poles. The floor is of strong timber, capable of sustaining three or four hundred tons. The crib stands in a strong wooden pan, three or four feet larger than the square of the crib, so as to catch all the droppings. The pan is about three feet deep, and tightly caulked. A small quantity of water is kept on the bottom of the pan, for the double purpose of saving the oil in case of a leak, and for purifying it from the blood, and any other foreign matter of a higher density. The oil extracted by this process is all cold-drawn, which accounts for the disagreeable odor of seal oil. When the vats begin to run, the oil drops from the crib upon the water in the pan, and as it accumulates it is drawn off into casks, and is ready for exportation. The first running, which is caused by compression from its own weight, continues from two to three months, yielding what is termed *pale* seal oil, until from fifty to seventy per cent. is drawn off, according to the season, and also in proportion to the quantity of old seal fat put into the vat. Owing to its toughness, the latter does not yield to compression, nor does it give up its oil until decomposition sets in; and hence it does not, by this process, yield pale seal oil. As putrefaction proceeds, the color changes to straw; and, as the season advances, becomes every day darker, and a more nauseous odor is eliminated, until the brown oil at last runs out. As this running slackens, it becomes necessary to turn over what remains in the vats. The crib being generally divided into nine apartments, or *pounds*, this operation is performed by first emptying one of these, and dispersing the contents over the others, and then by filling and emptying them alternately, the entire residue—a complete mass of putrefaction—is turned over. By this means a further quantity of brown oil is obtained. The remains are then finally boiled in large iron pots, which during the whole season are in constant requisition for boiling the cuttings and clippings of the skin, and other parts of the pelts, which it is unadvisable to put into the vats. The produce of this, and the remains of the

pelts, are what is termed *boiled seal oil*. The refuse from the vats is found to be very valuable manure, and is readily purchased by the farmers in the neighborhood.

S. G. ARCHIBALD, of Newfoundland, has devoted much attention to the improvement of the method of extracting seal oil, and states that the different kinds of seals' fat, if taken while fresh, and subjected to a process of artificial heat, are capable of yielding not only a uniform quality of oil, but the oil so obtained is much better in quality than the best prepared by the old process, and free from the unpleasant smell common to all seal oil. He afterwards invented a steam apparatus for rendering seal and other oils, which is said to answer the purpose admirably.

Seal oil is used solely for illuminating purposes, and when tolerably pure, answers admirably, giving a beautiful, brilliant light, and producing no offensive smell, nor any clogging of the wick. Owing to the offensiveness it communicates to its salts, it is not applicable for the production of soap.

Porpoise Oil.—This, the produce of the *delphinus phocena*, much resembles whale oil. It is liquid, and has a yellow color. When freshly extracted, it has a fishy smell, but by exposure to sun and air becomes nearly inodorous. It then, however, acquires an acid reaction. It is soluble in about five parts of boiling absolute alcohol, but a portion of its solid constituent is deposited on cooling. By saponification it yields glycerin, with oleic, margaric, and phoenic acids.

Shark Oil.—This oil is procured from the liver of the basking shark—*squalus maximus*—of the bay of Galway, or sun-fish, as it is commonly called. The quantity of oil obtained from a single fish frequently amounts to one hundred and twenty gallons. It is light-yellow, of specific gravity 0·870 to 0·876, and retains its fluidity several degrees below the freezing point of water. It is said to give a brilliant flame, and without clogging the wick. RONALDS, who made a partial examination of it, reports that it consists of glycerin, a peculiar oleic acid, very rich in carbon, and another undefined liquid oil.

COD-LIVER OIL.—This oil is extracted from the liver of the common cod, and various other allied species of fish, but principally from the above—*gadus morrhua*—and the ling—*lota molva*. PENNANT describes the

method pursued in Newfoundland for its extraction as follows:—They take a half-tub, and boring a hole through the bottom, press hard down into it a layer of spruce boughs, upon which they place the livers, and expose the whole apparatus to as sunny a place as possible. As the livers corrupt, the oil runs from them, and straining itself through the spruce boughs, is caught in a vessel set under the hole in the tub's bottom. According to Dr. DE JONGH, the usual mode of preparation in Norway is to store the livers in vats or tubs as soon as they are separated from the fish, where they are left until the end of the fishing season, when the oil that has separated is decanted, and forms the pale oil of commerce. The residue of the livers, being then submitted to heat, yields the darker oil. The best English oil, according to Dr. GARROD, is thus prepared:—The livers are collected daily, so that no trace of decomposition may have occurred, carefully examined, in order to remove all traces of blood and impurity, and to separate any inferior livers; they are then sliced and exposed to a temperature not exceeding 180°, until all the oil has drained from them. This is filtered, afterwards exposed to a temperature of about 50°, in order to congeal the bulk of the margarin, and again filtered and put into bottles well secured from the action of the air. In TAYLORS', every liver is opened, examined, washed free from blood, and, if sound and fit for use, is cut in pieces and put with others into a large pan with a portion of water. To the external surface of this pan steam is admitted, and the temperature being very carefully adjusted to about 180°, the livers are heated for a sufficient length of time to allow of the complete separation of the oil. The result of this process is the production of a sweet and nearly colorless oil, which is skimmed off and filtered through flannel. This, having been congealed for the separation of its margarin, is again filtered when required for use.

Three varieties of cod-liver oil are met with in the English market, and are known as the pale, the light-brown, and the dark-brown or black. The first is that extracted from the livers before putrefaction has commenced; the two latter have either remained longer in contact with the livers, have been prepared at high temperatures, or have been obtained from livers in a state of decomposition. Appended is Dr. DE JONGH's analysis of the three varieties:—

	Pale oil.	Brown oil.	Black oil.
Oleic acid, with gaduin and two other bodies,.....	74·03300	71·75700	69·78500
Margaric acid,.....	11·75700	15·42100	16·14500
Glycerin,.....	10·17700	9·07300	9·71100
Butyric acid,.....	0·07436	—	0·15875
Acetic acid,.....	0·04571	—	0·12506
Fellinic acid, and cholic acids, with a small quantity of margarin, } olein, and bilifulvin,.....	0·04300	0·06200	0·29900
Bilifulvin, bilifellinic acid, and two peculiar substances,.....	0·26800	0·44500	0·87600
A peculiar substance, soluble in alcohol,.....	0·00600	0·01500	0·03800
A peculiar substance, insoluble in water, alcohol, and ether,.....	0·00100	0·00200	0·00500
Iodine,.....	0·03740	0·04060	0·02950
Chlorine and traces of bromine,.....	0·14880	0·15880	0·08400
Phosphoric acid,.....	0·09135	0·07800	0·05365
Sulphuric acid,.....	0·07100	0·08595	0·01010
Phosphorus,.....	0·02125	0·01136	0·00754
Lime,.....	0·15150	0·16780	0·08170
Magnesia,.....	0·00880	0·01230	0·00380
Soda,.....	0·05540	0·06810	0·01790
Iron,.....	—	—	a trace.
Loss,.....	3·00943	2·60319	2·56900
	100·00000	100·00000	100·00000

Of the three varieties of cod-liver oil, the most colorless, prepared entirely from fresh livers, is to be preferred, as it possesses the constituents of the oil in the purest state, and is, therefore, the most valuable as a therapeutic agent. From the investigation of several medical men, who have devoted much attention to the investigation of the therapeutic value of the several kinds of oils, the following may be gleaned in favor of the pale variety:—It is the real oil, as contained in the liver of the cod-fish—rich in biliary matters, and also in iodine and other inorganic principles; it contains no products of putrefaction, such as are found in the dark oils; it sits more easily on delicate stomachs; and experience has proved it to be a most effective therapeutic agent.

Adulteration.—Cod-liver oil is said to be extensively adulterated, and in some cases, indeed, an entire substitution is stated to be made, consisting of train oil, admixed with iodine, either in the free state, or as an alkaline iodide. This addition of iodine, or an iodide, may be readily detected by adding a solution of starch and a little sulphuric acid, when the blue iodide of starch is instantly developed.

Physiological Effects.—In the dose of a tablespoonful, cod-liver oil acts as a laxative, diaphoretic, and diuretic. The disagreeable flavor, especially of the dark-colored varieties, occasionally creates nausea and sickness, but when habit has surmounted the repugnance to it, these effects cease. In several cases it has proved an emenagogue, and on some occasions it has given rise to a cutaneous eruption. Dr. BARDSLEY found that most persons were disposed to fatten under its use. According to Dr. THOMPSON and others, the olein is the active agent, while the presence or absence of iodine, bromine, *et cetera*, in the infinitely small proportions in which they are met with as constituents of the oil, cannot affect the results of its administration, and, in the opinion of Dr. WILLIAMS, cod-liver oil affords fat of a better kind, more fluid, less prone to change, and more capable of being absorbed into the structure of the body, than other forms of fat. Cod-liver oil has proved most useful in such cases as are of a gouty, rheumatic, scrofulous, or phthisical nature. But even in these it requires a long-continued use to prove successful. The oil is best adapted for relaxed, torpid, and phlegmatical temperaments, and for scrofulous subjects. The dose at the commencement for an adult is a tablespoonful, which has been sometimes increased to six times this quantity, and when given immediately after a farinaceous meal, and without any vehicle, rarely creates nausea or vomiting.—*Pereira*.

Sperm Oil.—This oil is obtained from the white whale—*physeter macrocephalus*. This, termed also the *cachalot* and sperm whale, is remarkable for the enormous size of its head, which is square, and apparently cut off in front. The animal is pursued chiefly for this oil, but it yields also *ambergris*. The oil is met with in several parts of the body, but the head is the principal receptacle of it. Here it is found in a large excavation of the upper jaw, anterior to, and quite distinct from, the true cranium which contains the brain. Like the fat of other animals, this oil is contained in cells, or cellular membrane; but besides these cells,

there are also ligamentous partitions going across, which serve as supports for the enormous quantity of oil of which the bulk of the head is principally made up. Sperm oil is extracted from the *case* by means of an opening made in the triangular-shaped cavity situated in the right side of the nose and the upper surface of the head, and the liquid contents are removed by a bucket. The dense mass of cellular tissue beneath the *case* and nostril, and which is technically called *junk*, also contains oil. Directly it leaves the skull of the animal, the oil begins to deposit large quantities of *spermaceti*, in the form of small crystalline laminae, from which the oil flows out by pressure, and is subsequently purified by the addition of a small quantity of solution of potassa, which precipitates certain matters by neutralizing the acid that held them in solution. Sperm oil is of a yellow color, has a slightly unpleasant smell, and is well suited for burning in lamps. It saponifies easily, and the soap obtained is brown, rather soft, and entirely soluble in water. According to HOFSTADTEN, it contains spermaceti, oleic, valerianic, and physetoleic acids. The formula for the latter is $C_{32}H_{20}O_3$, HO. It is colorless, inodorous, melts at 86° , and solidifies at 82° . It does not yield sebaccic acid by distillation, nor elaidic acid by the action of nitrous acid.

ADULTERATION OF OILS.—The enormous consumption of the various kinds of oils in the arts, manufactures, and other purposes, renders it a point of great importance to be able to detect the admixture of one oil with another of inferior quality, inasmuch as, owing to the physical similarity of the several varieties, great temptation exists for the commission of such frauds. The admixture of fish oil with animal or vegetal oils may be readily detected by the brown or black hue produced by the action of a stream of chlorine, and also, according to CALVERT, by the reddish coloration developed by boiling a mixture of the oil with solution of caustic soda. For the detection of a mixture of a siccative with a non-drying oil, several methods may be applied, as that of POUTET, which consists in the application of protonitrate of mercury, by which the non-drying oils yield claidin; or that of BOUDET, which depends upon the same reaction, to produce which, however, nitrous acid is substituted for the mercury salt; and, in addition, the reaction discovered by MAUMÉNE, who showed that the non-drying oils give rise to a much higher temperature, when mixed with strong sulphuric acid, than is the case with those belonging to the class of siccatives. The fixed oils which may be solidified by BOUDET's method are those of sweet almonds, of filberts, and of colza; and of the drying oils, castor oil only is solidified by this treatment. One hundred parts of the oils mentioned, when treated by a mixture of nine parts of nitric acid with one of peroxide of nitrogen, require different lengths of time to become solid, as shown in the table subjoined:—

Oils.	Color developed by addition of the mixture.	Number of minutes required for congelation.	Proportion.
Olive oil,	Greenish-blue,	73	10.0
Sweet almond oil,	Dirty-white,	160	22.2
Oil of filberts,	Greenish-blue,	103	14.0
Oil of acajou,	Lemon-yellow,	40	6.0
Castor oil,	Golden-yellow,	603	82.6
Colza oil,	Yellowish-brown,	2400	328.0

HEIDENREICH determines the purity of the fixed oils, and the admixture of cheaper oils, approximately, as follows:—First, by observing the peculiar smell of the oil when gently heated in a small porcelain or platinum capsule, by means of a spirit lamp. The odor evolved will resemble that of the plant or animal from which it was obtained. This characteristic is said to be valuable if observed in conjunction with the genuine oil, and to furnish accurate indications of the presence of linseed, whale, train, or rape oils, in any mixture. The smell of the oil, however, as observed by PERROT, is not always a safe criterion, since an oil of the same fruit or nut has not always the same odor, but differs with the climate where produced, and the varied mode of extraction. HEIDENREICH further applies concentrated sulphuric acid, in the proportion of one or two parts per cent. of oil, and by this admixture a very intense action immediately ensues, the temperature rises, and the mixture becomes colored. A few drops of the oil are placed on a glass plate, having a sheet of white paper underneath; and to the oil is added a small drop of sulphuric acid, of specific gravity 1.632, when, according to the oil employed, a characteristic color will be developed without stirring. In the case of *rape oil*, a greenish-blue ring gradually forms at a certain distance from the acid; whilst towards the centre, where the action is more intense, light yellow-brown streaks may be observed. With *oil of black mustard*, the reaction much resembles that of rape oil, but is more violent. In *train oil*, a very peculiar

motion occurs, commencing at the centre, and extending to the outside; at the same time a red tint appears, which grows more and more vivid, until after ten or fifteen minutes the margin assumes a violet tinge, which, in about two hours, is uniform throughout. *Olive oil* instantly becomes pale yellow, and afterwards yellowish-green. In *poppy and sweet almond oils*, the color developed resembles that of the greenfinch, but afterwards becomes of a dead yellow hue. In *linseed oil*, a beautiful dark brownish red web is formed, gradually changing into brownish-black. Lastly, *tallow oil* is rendered brown.

If, in the process of HEIDENREICH, instead of the acid being allowed to act on the oil undisturbed, the two liquids are stirred together by means of a glass rod, the phenomena vary from those above described.

PERROT, reviewing the process of HEIDENREICH, directs twenty drops to be employed; and instead of the glass-plate and white paper, he uses capsules of white porcelain. In the place of sulphuric acid, he used also a saturated solution of bichromate of potassa in this acid, and in the proportion indicated above, namely, one drop to twenty of oil. In applying this method, it is always necessary, to insure greater certainty, to compare the effects upon the oil to be examined, with an oil the purity of which is undoubted. The appended table shows the reactions produced by sulphuric acid alone, and by the solution of bichromate in the acid:—

Oils.	Sulphuric Acid.		Solution of bichromate of potassa in sulphuric acid
	Not stirred.	Stirred.	
Tallow oil,.....	Reddish spots with reddish circles.	Reddish-brown.	Reddish-brown.
Sweet almond oil,	Greenfinch yellow, with orange spots.	Dirty-green.	Yellowish small lumps.
Train oil,	Brown small lumps on a brown ground.	Lees of wine.	Brownish-red small lumps on a red ground.
Hemp-seed oil,	Reddish small lumps on a yellow ground.	Greenish-brown.	Yellow small lumps on a green ground.
Rape-seed oil,.....	Scarcely perceptible spots, or slight green coloration.	Green.	Yellow small lumps on a green ground.
Fish-liver oil,	Dark-red.	Dark-red.	Dark-red.
Linseed oil,.....	Reddish-brown.	Clotted on a grey or green ground.	Brown small lumps on a nearly colorless or slightly green ground.
Oil of <i>madia sativa</i> ,	Slightly reddish-brown, underneath a film inclining to grey.	Olive-green.	Light-brown small lumps on an olive-colored ground.
Nut oil,.....	Yellowish-brown.	Clotted dark-brown.	Small brown lumps.
Olive oil,.....	Yellow, or orange-yellow.	Dirty-brown.	Brown.
Poppy oil,	Yellow, or greenish-yellow spots.	Olive or slightly green.	Small yellow lumps on a yellow or colorless ground.
Neat's-foot oil,.....	Yellow slight spots.	Dirty-brown.	Brown spots on a similar ground.
Castor oil,	Yellow slight spots.	Almost colorless.	Slightly green.

The action of the reagent upon the oil is not the same under all circumstances, but differs with the place of its growth, the manner of pressing, and its age. If, however, any oil be examined comparatively with a perfectly pure one, the proof of sophistication may be rendered pretty certain by observing the difference. After the discovery of fraudulent admixture, the oil is tested to ascertain the adulterant, either by reagents, or by the odor evolved when gently heated as before men-

tioned. This having been found out, small quantities of the suspected oil are added to a perfectly pure sample of the kind of oil under examination, and by this means the proportion of the mixed oils may be approximately estimated. Several cases of adulterated oils have lately been submitted to the Editor; and by carefully observing the reactions specified he has been able to state, to a certainty almost, the percentage of foreign oil in each sample.

GENERAL TABLE OF REACTIONS.

Oils.	Caustic soda, spec. gravity 1.340.	Sulphuric acid, spec. gravity 1.475.	Sulphuric acid, spec. gravity 1.530.	Sulphuric acid, spec. gravity 1.635.	Nitric acid, spec. gravity 1.180.	Nitric acid, spec. gravity 1.220.	Nitric acid, spec. gravity 1.380.	+ Caustic soda, spec. gravity 1.340.	Phosphoric acid, syrupy.	Sulphuric acid + nitric acid.	Aqua regia. + Caustic soda, spec. gravity 1.340.
Olive,.....	slight yellow.	green tinge.	greenish-white.	light-green.	greenish.	greenish.	greenish.	fluid white mass.	slight green.	orange- yellow.	—
Gallipoli,....	ditto.	ditto.	grey.	brown.	ditto.	ditto.	ditto.	fibrous white mass.	ditto.	dark- brown.	—
India nut,...	thick and white.	—	dirty white.	light-brown.	—	—	—	ditto.	—	orange- white.	—
Pale rapeseed,	dirty yellowish- white.	—	pink.	brown.	—	—	—	fluid white mass.	—	dark- brown.	—
Poppy,.....	ditto.	—	dirty white.	—	—	yellowish-red.	red.	light-red fluid mass.	—	slight yellow.	—
French nut,...	ditto.	brownish.	grey.	brown.	yellow.	red.	dark red.	fibrous red mass.	brown yellow.	dark- brown.	yellow.
Sesame,	ditto.	green tinge.	greenish dirty white.	—	orange- yellow.	ditto.	ditto.	fluid red mass with brown li- quor beneath.	—	green, be- coming in- tense red.	ditto.
Castor,.....	white.	—	dirty white.	—	—	—	—	fibrous white mass.	—	brownish- red.	—
Hempseed, ..	thick brownish- yellow.	intense green.	intense green.	intense green.	dirty green.	greenish dirty brown.	greenish dirty brown.	fibrous light brown mass.	green.	green, becoming black.	green.
Linseed,.....	fluid yellow.	green.	dirty green.	green.	yellow.	yellow.	green becom- ing brown.	fluid yellow mass.	brown yel- low green.	ditto.	greenish- yellow.
Lard,.....	pinkish white.	dirty white.	dirty white.	light-brown.	—	—	very slight yellow.	fluid mass.	—	brown.	—
Neat's-foot, ..	dirty-yellowish white.	yellow tinge.	brownish dirty white.	brown.	light-yellow.	light-yellow.	light-brown.	fibrous white mass.	—	dark- brown.	slight yellow.
Sperm,.....	dark-red.	light-red.	red.	intense brown.	slight yellow.	ditto.	red.	fluid mass.	dark-red.	dark- brown.	ditto.
Seal,.....	ditto.	ditto.	ditto.	ditto.	pink.	light red.	ditto.	ditto.	ditto.	ditto.	ditto.
Coal liver,...	ditto.	purple.	purple.	ditto.	—	—	ditto.	ditto.	ditto.	ditto.	yellow.

Another systematic method for testing the purity of oils, for which chemists are indebted to CALVERT, has been lately published, and goes far to solve this most intricate department of analytical chemistry. It consists in the employment of caustic alkali, and of various acids at different degrees of dilution, as well as mixtures of acids, and of acids and alkalies, successively applied. The preceding table, constructed by this chemist, indicates the reactions depended upon. The first test in the list is employed in the proportion of one volume of solution to five of oil, and is especially valuable to distinguish fish from other vegetal and animal oils. The test and oil are to be well mixed, and then heated to the point of ebullition. In the case of sulphuric acid, the same proportions as of caustic soda are employed in each case, and the mixture well agitated. With the acid, of specific gravity 1.475, the appearance is noted after standing fifteen minutes; with that of 1.530 after reposing five minutes; and with that having the density 1.635, after two minutes. With nitric acid, the mixture is made in a like proportion in each case, and the reaction noticed after five minutes. The caustic soda and nitric acid are applied together, by adding ten volumes of the former to five of the oil which has just been acted upon by one of nitric acid. The phosphoric acid is employed precisely as the other acids, and is extremely sensitive in the case of fish oils. The sulphuric and nitric acids are used in the proportion of one volume of a mixture of equal measures of acid with five of oil, and the appearance is observed after the lapse of two minutes. This test is especially applicable to the detection of oil of sesamum in admixture with other oils. Lastly, the aqua regia employed is composed of twenty-five volumes of hydrochloric acid, of specific gravity 1.655, and one of nitric acid, of specific gravity 1.330, and is allowed to remain at rest about five hours. The reactions given are those that ensue when a mixture of five volumes of oil with one of aqua regia is agitated, and allowed to stand five minutes. On the subsequent addition of caustic alkali to this mixture, a very vivid and distinct coloration is perceptible in many cases, and this, with the other appearances mentioned, render this last a most valuable agent for the detection of several instances of admixture.

STATISTICS.—Of the six principal vegetal oils, namely, palm, cocoa nut, castor, olive, linseed, and rape, the first four are imported in the state of oil only; the last two, chiefly as seed. The following table exhibits the proportions of the latter imported in the year 1850:—

	Linseed. Quarters.	Rapeseed. Quarters.
Russia,	482,813	3,235
Sweden,	870	—
Norway,	268	—
Denmark,	37	3,092
Prussia,	87,273	645
Hanse Towns,	1,153	2,872
Holland,	7,734	201
Naples,	1,476	—
Austrian territories,	40	2,480
Greece,	—	1,637
Wallachia and Moldavia, ..	910	1,280
Egypt,	17,517	—
East Indian empire,	26,142	13,126
Miscellaneous,	262	922
Total,	626,495	29,490

The quantity of the four principal vegetal oils imported in 1850 and the preceding two years, is shown by the following table:—

	Hundredweights		
	1848	1849	1850
Palm oil,	510,218	493,331	446,588
Cocoa-nut oil,	85,463	64,452	98,040
Castor oil,	4,588	9,681	—
	Tons.		
Olive oil,	10,086	16,854	20,783

The proportion in which these oils were furnished from various countries in 1849, was:—

	Palm oil. Hundredweights.	Olive oil. Tons.	Castor oil. Hundredweights.
Western Africa,	475,364	1	—
United States,	13,349	—	230
Naples and Sicily,	14	9,661	—
East Indies,	—	—	2,315
Canary Islands,	3,719	—	—
Malta,	—	2,237	—
Turkish Empire,	—	1,712	—
Tuscany,	—	892	—
Spain,	—	753	—
Brazil,	525	—	—
Ionian Islands,	—	545	—
Morocco,	—	308	—
Madeira,	353	—	—
Sardinia,	—	333	11
Miscellaneous,	7	451	5
Total,	493,331	16,854	2,581

The subjoined table exhibits the proportions of the several fixed oils and seeds entered in the port of Liverpool in 1849 and 1850, from the countries named:—

Oils.	Countries.	1849 Tons.	1850 Tons.
Poppy seed,	—	—	—
Ground nut,	—	89	90
Castor,	East and West Indies.	5	45
Castor seed,	Lisbon,	—	79
Rape,	Antwerp,	6	15
Rapeseed,	Antwerp,	3	5
Olive,	Manilla,	56	8
"	Barbary,	2,785	2,330
"	Malaga,	246	—
"	Levant,	1,243	2,100
"	Corfu,	280	762
"	Leghorn,	—	15
"	Palermo,	2,785	8
"	Gallipoli,	2,429	4,511

At the Great Exhibition a class of substances was exhibited, under the head of OILS, which are likely to prove of great commercial importance, as they possess properties differing from the finest vegetal oils; and some of them can, it appears, be supplied in large quantities, and at moderate cost. The jury, with a view to mark their appreciation of this class, awarded a prize medal to R. CLARENCE, Cape of Good Hope, for oil obtained from sheep's tails; and honorable mention to several exhibitors from the United States for oil obtained from lard, by pressure, at a very low temperature. The collection of oils exhibited by the East India Company was very extensive, and contained a large number of highly interesting specimens.

In concluding this article, the Editor must express his thanks to his talented student, Mr. J. W. KYNASTON, of Lincolnshire, for his very kind and valuable assistance.

OPIUM—English, French, German, and Latin—is the inspissated juice of the head of the poppy—*Papaver somniferum*. The word is derived from the Arabic *afium*. The poppy is very extensively cultivated in Asiatic Turkey, Egypt, Persia, India, and occasionally in France, Germany, and England. The young plants are set in rows, about six inches asunder, and at first watered abundantly. When about six or eight inches high they are richly manured, and again abundantly irrigated as they are about to flower. When the capsules or seed vessels are nearly full-grown, the collection of the opium commences. For this purpose a body of women or children go over the fields about sunset, and make a number of parallel longitudinal incisions in each head, taking care not to

FIG. 377.



FIG. 378.

penetrate into the cavity where the seed is lodged. This is done with sharp shells, or preferably with a knife called a *nushkur*, which consists of three or four blades tied together, so as to make fine parallel gashes. Through these incisions the juice flows, and is scraped off early in the morning, and put into earthen pots, to be dried

in the sun. To this is frequently added an inferior matter, obtained by subjecting the heads to pressure, and even by boiling the heads in water, and concentrating the extract. The greatest yield of good opium in India is stated at forty-one pounds per acre, and the average at from twenty to twenty-five pounds.

VARIETIES.—The quality of opium varies greatly, according to the country where it has grown, the species of poppy cultivated, the nature of the season, and the care taken in its collection and preservation. Some varieties are inferior to others, in the ratio of three to one. In the European markets the preference is given to the opium of Smyrna. This sort comes into the market in soft lumps, of greater or less bulk, the surface of which is covered with dock seeds, from the leaves in which they have been folded. It is light-colored internally, but the surfaces, when broken or cut, darken on exposure to the air. The smell is strong and peculiar, and the taste bitter and acrid. It contains ten to fourteen per cent. of morphin.

The opium of Constantinople is found in regular flat cakes or loaves, covered with poppy or tobacco leaves. It is drier than the Smyrna variety, and even brittle. In the hand it softens, and furnishes a fawn-colored paste, which turns brown on exposure to the air. It smells like the Smyrna opium, but fainter. Its yield of morphin is six or seven per cent.

The Egyptian or Alexandrian opium comes into the market in small, very dry, and very flat loaves, very clean at the surface, and showing scarcely a trace of the leaves in which they have been folded. Its color is dark-brown; its fracture clean and shining. It has a very feeble smell, and contains only three or four per cent. of morphin.

The opium of India is found in rounded masses of a darker hue, and more smooth and soft texture. It has an empyreumatic smell, and a less bitter but more nauseous taste. It is wholly soluble in water, and contains more or less sulphate of lime. Its per centage of morphin is two to five.

English and German opium resembles the East Indian in appearance, but is lighter in hue, and in quality equals the very best Smyrna. Opium collected in France has yielded sixteen to twenty-eight per cent. of morphia. The fickleness of the climate, and above all things the high price of labor, render it very improbable that opium can ever be advantageously cultivated in Western Europe.

PROPERTIES.—Genuine opium has a heavy narcotic smell, a very disagreeable bitter taste, with a warmish and subacid after-taste. It should be of a rich deep fawn color, or brown, of a tough plastic consistency, and a smooth uniform texture, marking paper with an interrupted streak. Its specific gravity is 1.336, which is one of the proofs of its purity, as few vegetal substances are so heavy, except gum-arabic and opoponax. Bad opium wants the peculiar narcotic odor; it is friable or soft, full of dark-brown or black patches, or is all of a deep black, marks with a continuous brown streak, tinges water yellow, easily melts when exposed to heat, and tastes sweetish.

Opium is soluble in water, alcohol, and ether, and more readily in proof spirit. It also dissolves in acetic, citric, or any of the vegetal acids in solution. Boiling water dissolves about forty-one per cent., holds fifty per cent. in solution, and leaves the remaining nine untouched.

Opium is of an exceedingly complicated nature. Besides moisture, gum, caoutchouc, lignin, and bassorin, it contains at least thirteen or fourteen distinct principles, most of which occur in no other substance. Of these, nine are of a basic or alkaline nature—morphin, codein, narcotin, narcein, paramorphin, papaverin, opianin, narcogenin, and pseudomorphin; two are neutral, meconin and porphyroxin; whilst four, meconic acid, a brown extractive matter, a resin, and a fixed oil, possess acid properties; and an essential or volatile oil is too little known to admit of classification.

These substances occur in varying proportions, some of them in very minute traces, whilst others are in many samples entirely wanting. It is still doubtful whether all actually exist as such in crude opium, or whether some of them are not *alteration products*, formed by the influence of the reagents used to effect their extraction. It is also questionable, as far at least as the basic constituents of opium are concerned, whether they are totally distinct and unconnected principles, or merely successive modifications of one or two bodies.

PROXIMATE PRINCIPLES.—The Editor will next pass to a description of the various constituents of opium, with their methods of extraction.

Morphin.—This, the most important constituent of opium, was discovered in 1816 by SERTURNER. Its composition is indicated by the formula $C_{35}H_{20}NO_6$, and its symbol is M. It crystallizes in four-sided prisms of an adamantine lustre, containing two equivalents,

or 5.73 per cent. of water, which is expelled at 248°. At higher temperatures it fuses into a yellow liquid, and is subsequently decomposed.

This alkaloid is inodorous, strongly bitter, insoluble in cold water. It dissolves in ninety-two parts of boiling water, and is again deposited in crystals as the solution cools. It dissolves in forty parts of anhydrous alcohol, and in about thirty of proof spirit at a boiling temperature. It is sparingly soluble in ether, but readily in the fatty and essential oils. It dissolves in the fixed caustic alkalies, and to a small extent in ammonia. In nitric acid it dissolves with a blood-red color. Morphin ranks amongst the more powerful bases; its solutions redden turmeric paper, and turn violet paper green. If thrown in powder into a saturated solution of the sesquisulphate of iron, as nearly neutral as possible, it strikes a blue color. The sulphate of this base is formed whilst the iron, reduced from sesquioxide to protoxide, combines with *morphic acid*, a product of the decomposition of a part of the morphin. Morphin decomposes iodic acid in solution, setting the iodine free, whilst the other organic ingredients combine with the acid to form iodates. This reaction is, therefore, used for the detection of morphin. The solution in question is rubbed in a mortar with a little mucilage of starch. A few drops of iodic acid, or of a dilute solution of the perchloride of iodine, are then added. The blue tint which iodine forms with starch is, in this case, a proof of the presence of the alkaloid.

Where alcohol is dear, the process of GREGORY and ROBERTSON will be found preferable. These chemists extract a known weight of opium in cold water, and evaporate to the consistence of sirup. It is then redissolved in water, and again concentrated. To the boiling liquid dry chloride of calcium is added, in the proportion of nearly one-fourth of the opium employed. The chloride of calcium must be perfectly free from iron, otherwise the deep-red meconate of iron will be produced, and greatly impede the purification. The hot liquid is now mixed with cold water, which throws down meconate and sulphate of lime, coloring matter, resin, and the volatile oil of opium.

The precipitate is filtered off, and the clear liquid concentrated, when a fresh deposit of meconate of lime will be formed. Filter again, wash the precipitate on the filter with a little cold water, and add the washings to the filtrate. This is now evaporated down to the consistence of sirup, and allowed to stand for some days. There is then obtained a crystalline mass—a double salt of morphin and codein—and a dark mother-liquor, containing an acid meconate of lime, a little morphin, and the narcenin, meconin, narcotin, and paramorphin.

The crystalline mass is drained, pressed between sheets of bibulous paper, redissolved in water, acidulated with a very little hydrochloric acid, and evaporated to crystallization. The mother-liquor, on concentration, generally yields a further deposit. The crystals are redissolved in hot water, the solution neutralized with a little chalk, and treated with animal charcoal. The amount of water must be enough to retain the salt in solution on cooling, and the temperature must not exceed 190°. After twenty-four hours the solution is

filtered, and a few drops of acid added, which favors the crystallization. The crystals are redissolved and again crystallized, pressed between bibulous paper and dried in the stove. The mother-liquor is treated in the same manner with chalk and charcoal.

The salt obtained in this manner is a double one, free from narcotin. It is dissolved in water, boiled, and treated with ammonia, which precipitates the morphin. This is filtered off, washed with a little cold water, and dried. From the filtrate codein is obtained.

Morphin is often contaminated with narcotin, which may be entirely removed by ether, or the impure mass may be treated with very dilute acetic acid which dissolves the former, leaving the latter untouched. To determine the purity—from narcotin—of any sample of morphin, it may be dissolved in hydrochloric acid, and treated with caustic potassa in excess, in which the morphin will entirely dissolve, while any narcotin present remains untouched. If a very small portion of morphin is placed in a watch-glass with a little pure sulphuric acid and an equal quantity of water, and if a particle of bichromate of potassa be added, a rich green color appears, which changes, first to a copper green, and finally, to a dark dirty green.

The salts of morphia are mostly crystalline, bitter, very soluble in alcohol, but insoluble in ether. They are precipitated from their solutions by alkaline carbonates; caustic alkalies added in excess redissolve the precipitates. They are thrown down by infusion of gall nuts; they strike a blue color with the neutral sesquisalts of iron, and decompose iodic acid in the same manner as free morphin. Terechloride of gold precipitates the salts of morphin with a yellow color, which changes to blue. Nitrate of silver communicates to them a blackish-grey color, and is gradually reduced.

Codein was discovered by ROBQUET in 1833. The anhydrous substance consists of $C_{55}H_{20}NO_5$. ANDERSON and REGNAULT give the formula $C_{56}H_{21}NO_5$. By solution in water, or in aqueous ether, it is obtained in crystals often of considerable size, belonging to the right prismatic system, but presenting a considerable number of modifications. These crystals contain two equivalents, or 5.67 per cent. of water, which they lose at elevated temperatures, and at 302° fuse without decomposition or volatilization. One hundred parts of water at 60° dissolve 1.26 of codein, at 110°, 3.7, and at 212°, 5.9 parts. If more codein is present than boiling water can dissolve, the undissolved portion fuses and forms a kind of oily layer at the bottom of the vessel. It dissolves in alcohol, more readily when hot than when cold, and is taken up very freely by ether. It is insoluble in very highly concentrated solutions of potassa, which, joined to its behavior with ether, distinguishes it from morphin.

Codein is a very powerful base; it turns red litmus paper blue, and precipitates the oxides of lead, iron, cobalt, and nickel from their solutions. It is precipitated from the solutions of its salts by potassa and by ammonia; in the latter case, however, it does not fall immediately, but is slowly deposited as small transparent crystals.

Codein is obtained from the last filtrate in GREGORY and ROBERTSON'S process for preparing morphin. As

the codein forms only from one-sixteenth to one-thirtieth of the morphin, it is of course mixed in this fluid with a corresponding amount of chloride of ammonia, which must first be decomposed by potassa. Much advantage is gained by first evaporating the liquid to crystallization, and pressing the crystals first deposited: as, however, they are but little less soluble than chloride of ammonia, this process must not be carried too far, or much of the codein will be wasted. The crystals so obtained are dissolved in boiling water, and a highly concentrated solution of caustic potassa is added in excess. Codein is in part precipitated as an oily liquid, which gradually concretes into a solid mass, and in part deposited as crystals when the liquid cools. By evaporating the fluid another crop of crystals is obtained, and finally, when the mother-liquor has been very highly concentrated, it is filled, on cooling, with morphin in long silky crystalline needles.

The crystals of codein thus obtained are dissolved in hydrochloric acid, boiled with animal charcoal, and reprecipitated with a slight excess of potassa. The precipitate is finally dissolved in ether, which ought to be free from alcohol, and allowed to crystallize.

The salts of codein are for the most part soluble and crystalline. Their solutions give with bichloride of platinum a pale-yellow pulverulent precipitate; with chloride of mercury a white precipitate, soluble in boiling water and alcohol; and with chloride of palladium, a yellow precipitate, which is decomposed on boiling, with separation of the metal.

Narcotin consists of $C_{46} H_{25} NO_{14}$. It is a white inodorous substance, forming prismatic crystals, which fuse at 338° , and solidify at 266° , the solidification being attended with a loss of weight amounting to three or four per cent. If it is cooled slowly, several centres of crystallization form at its surface and gradually increase in size. It is insoluble in cold, and requires five hundred parts of boiling water for solution. It dissolves in one hundred parts of seething alcohol, but is taken up more readily by this menstruum at the boiling point. It is very soluble in ether, in the fatty and the essential oils.

Narcotin is without action on the sesquisalts of iron, on iodic acid, and the terechloride of gold. Nitric acid colors narcotin an orange-red. In sulphuric acid, containing about one-thousandth of nitric acid, the liquid assumes in the course of seven or eight minutes an intense blood-red color, which the addition of more nitric acid destroys. Peroxide of nitrogen acts so energetically upon narcotin, that, if the quantity be not very small, ignition ensues in a few seconds.

To prepare narcotin, the grounds left after the extraction of opium by water are boiled with dilute acetic acid, the liquid is strained and filtered, and the clear liquid is precipitated by ammonia. The precipitate is then redissolved in strong boiling alcohol, along with a little animal charcoal. The solution is filtered whilst boiling, and, as it cools, narcotin is deposited in crystals.

Narcotin combines with the more powerful acids, forming salts which are intensely bitter. They are thrown down from their solutions by infusion of galls, and by the caustic alkalies; but the precipitate caused by the latter does not redissolve in excess.

Narcein— $C_{46} H_{29} NO_{18}$ —is extracted from the dark-brown mother-liquor obtained in the preparation of morphin. It is sparingly soluble in water, insoluble in ether, but very soluble in alcohol. It forms fine silky crystals, which have a metallic taste. It dissolves in dilute acids, but without neutralizing them, and the solutions on evaporation deposit narcein unaltered. It is colored blue by strong acids and by chloride of calcium, but not by sesquisalts of iron.

Paramorphin or *thebain*—was discovered by THIBOUMERY, and was examined by KANE, who assigns to it the formula $C_{33} H_{21} NO_6$. Paramorphin is strongly analogous to narcotin; but it crystallizes in short needles, fuses at a much lower temperature— 266° —is much more readily soluble in alcohol, and its taste is acrid rather than bitter. It has an alkaline reaction, and combines with acids, forming crystalline salts. It is obtained by extracting opium with excess of lime, treating the residue with a dilute acid, and precipitating with ammonia. The powder is treated by alcohol, which, on evaporation, leaves paramorphin in crystals.

Papaverin was first obtained by MERCK. It has the formula $C_{40} H_{21} NO_8$. It is insoluble in water, and sparingly soluble in cold alcohol and ether, but dissolves more freely on the application of heat, and is deposited in irregularly agglomerated, colorless, prismatic crystals. When moistened with concentrated sulphuric acid it acquires a deep-blue color. When treated with moderately strong nitric acid it is converted into a yellow crystalline mass. It restores the blue color of reddened litmus, and neutralizes acids, forming crystalline salts.

It is obtained by precipitating the aqueous extract of opium with soda, exhausting the precipitate with alcohol, and evaporating the brown tincture thus obtained to dryness. The dry resinous residue is dissolved in dilute acid, the liquid filtered and precipitated by ammonia, when a resinous matter is obtained which contains the papaverin. This is then redissolved in dilute hydrochloric acid, and precipitated with acetate of potassa. The precipitate is washed with water, and treated with boiling ether, from which, on cooling, the papaverin is deposited in crystals.

Opianin was discovered in Egyptian opium by HINTERBERGER. Its constitution is represented by $C_{42} H_{21} NO_{14}$. It was at first mistaken for narcotin. Opianin crystallizes in long colorless, transparent, diamond-like needles, of the prismatic system. It is inodorous, insoluble in water, and but sparingly soluble in boiling alcohol, from which, on cooling, it completely separates. The solution has a powerful and persistent bitter taste, suffers no alteration at the temperature of the water bath, and has a decided alkaline reaction. It is not affected by concentrated sulphuric acid, but dissolves in nitric acid with a yellow color. Sulphuric acid, to which nitric acid has been added, gives a blood-red tint, which after a short time passes into a straw-yellow. Opianin forms salts with the acids, and crystalline double compounds with the chlorides of platinum and mercury. From the solutions of its salts it is thrown down in white flakes. It was obtained by extracting the opium with water, adding ammonia to the solution, washing the precipitate obtained, first with water

and then with alcohol, and drying. It is now dissolved in alcohol, deodorized with animal charcoal, and separated from morphin by repeated crystallizations out of alcohol.

Narcogenin has been separated by BLYTH, and found to consist of $C_{30} H_{19} NO_{10}$.

Along with narcotin, to which, when perfectly freed from other compounds, BLYTH assigns the formula $C_{46} H_{25} N O_{14}$, WERTHEIM has discovered two other homologous bodies.

Pseudomorphin has been found in a few samples of opium by PELLETIER, according to the analysis of which it consists of $C_{27} H_{18} N O_{14}$. It forms shining scales sparingly soluble in water, insoluble in alcohol and ether, but soluble in alkalis. Like morphin it is colored blue by sesquisalts of iron. It dissolves in hydrochloric and acetic acids, but its salts have not been fully examined.

Porphyroxin or *opin*, is a neutral body, which crystallizes in colorless minute shining needles. When heated it melts, becomes resinous and friable. It is colored of an olive-green by strong nitric or sulphuric acids, and is dissolved by dilute hydrochloric acid, the solution turning red when boiled or allowed to stand. The acid solution is decolorized by alkalis, and yields with terechloride of gold a dirty-red precipitate, a rose-colored one with acetate of lead, and a brown with protochloride of iron. The solution is not changed by chlorine water, and takes a characteristic red tint. It is probably identical with sanguinarin and cholerythrin. Porphyroxin is prepared by taking the ethereal extract which, after exhaustion with water, remains from the preparation of meconin, and treating with boiling alcohol as long as anything is taken up. The crystalline mass which separates on cooling and evaporation is dried, dissolved in boiling alcohol, and treated with ammonia in excess. The precipitate formed is dissolved in hydrochloric acid, evaporated to a sirup, freed from any crystals that may separate, the liquid again precipitated with excess of ammonia, and the deposit taken up in boiling alcohol, when, on evaporation, porphyroxin separates in minute crystalline needles.

Meconin is a neutral, non-nitrogenous body, which does not form salts. It is prepared by exhausting powdered Smyrna opium with boiling ether. The residue, after distilling off the ether, is repeatedly boiled with water, the solution evaporated, the residue dissolved in ether, decolorized with animal charcoal, evaporated, and the meconia obtained recrystallized from water.

Meconic acid is best obtained in a state of purity by dissolving the pure meconate of potassa in eighteen parts of hot water, and adding two or three parts of concentrated hydrochloric acid. As the liquid cools crystals are deposited, which are redissolved in water, again treated with hydrochloric acid, and thus obtained entirely free from potassa. It should not be boiled in presence of any acid, as it is thus converted into komeinic acid.

Meconic acid forms beautiful pearly crystalline scales, of a harsh sour taste, sparingly soluble in cold, but more readily in hot water and in alcohol. The anhydrous acid consists of $C_{14} H O_{11}$, and is denoted by the symbol Me; the acid dried at 212° contains in addi-

tion three, and the crystalline acid nine equivalents of water.

By prolonged boiling in water the acid is decomposed, yielding komeinic, oxalic, and carbonic acids, besides a deep dusky-yellow coloring matter. Sulphuric and hydrochloric acids at 212° convert meconic acid into carbonic and komeinic acids. The same products, with the addition of water, are obtained on exposing meconic acid to a temperature of 248° ; but at greater heats the komeinic acid is again resolved into pyromeconic and carbonic acids. Caustic potassa or soda in excess converts meconic acid into oxalic and carbonic acids, and a brown matter not perfectly known. Charcoal readily absorbs meconic acid, and cannot, therefore, be used in its purification. Meconic acid and all its soluble salts give an intense blood-red color with the sesquisalts of iron, a reaction often employed for the detection of small traces of opium. It should be borne in mind that a very similar reaction with sesquisalts of iron is produced by indigotic acid and the alkaline indigotates, as well as by hydrosulphocyanic acid and the soluble sulphocyanides.

Meconic acid forms three classes of salts, containing respectively one, two, or three equivalents of base.

The bibasic meconate of potassa—Me, 2 KO HO—is obtained by adding a solution of caustic potassa to the crude meconic acid, obtained from the meconate of lime, till a greenish tinge begins to appear. A gentle heat is applied till the whole is dissolved. As the liquid cools, the impure salt crystallizes out in large quantities. This is purified by pressure between folds of bibulous paper, and repeatedly crystallized. This salt, which is used for the preparation of the pure acid, is sparingly soluble in cold water. The monobasic salt—Me KO, 2 HO—is formed by the cautious addition of hydrochloric acid; and the tribasic—Me 3 KO—by the addition of a proper quantity of caustic potassa. This salt is yellow and soluble.

Meconate of lime, an insoluble bibasic salt, is obtained by adding a solution of chloride of calcium to the infusion of opium, as in the process of GREGORY and ROBERTSON for preparing morphin. For the preparation of meconic acid, one part of this salt is mixed with twenty parts of boiling water and three parts of concentrated hydrochloric acid. As the solution cools, a monobasic salt—Me Ca O, 2 HO + aq—is deposited in silvery crystals. These are strained off, dried, and again treated in the same manner, avoiding a boiling temperature, till a crystal, heated upon platinum foil, leaves no residue of lime. The crude acid thus obtained is converted into meconate of potassa and purified, as stated above.

Meconate of sesquioxide of iron is a very soluble salt, of a blood-red color, which is decolorised by sulphurous acid and protochloride of tin.

The brown extractive acid requires further investigation. It is probably a mixture of different matters, and, perhaps, a product of alteration.

The resinous matter of opium contains nitrogen. It is brown, without smell or taste, insoluble in water and ether, but soluble in alcohol. It is softened by heat, and dissolves in alkalis. The oily matter has usually a yellow or brownish tinge, due probably to impurities.

It is acid and saponifiable. The essential oil has not yet been obtained in a state of purity.

The lignin, bassorin, gum, and caoutchouc require no remarks.

ESTIMATION.—Opium is most extensively adulterated, *perfectly genuine samples* being in fact very rare. The drug of commerce contains water, clay, sand, gravel, sulphate of lime, pieces of lead, dung of sheep and oxen, extracts of liquorice, of belladonna, of hemlock, eelandin, and lettuce, of *glaucium luteum*, bruised grapes freed from their stones, poppy stalks and husks, previously beaten up with white of egg, aloes, gum-arabic, and tragacanth. Sometimes also the grounds of opium, from which the morphin has been extracted, are sold as the entire drug.

The amount of water may be ascertained by drying a weighed portion in the steam bath, and noting the loss. Mineral adulterations may be detected by incinerating a known quantity of the drug, and weighing and examining the residue.

Generally speaking, however, the only satisfactory method of testing opium is to determine the quantity of morphin which it contains.

For this purpose GUILLERMONT recommends to take two hundred grains of the sample to be tested, cut it in slices, and rub it well in a mortar with four times its weight of alcohol, strain it through linen, squeeze the residue, and pour upon it three hundred grains more alcohol; mix the strained liquors together in a wide-mouthed flask, and add about sixty grains of ammonia. In twelve hours the morphin will be spontaneously separated in crystals. These are thrown upon a filter, washed with a little water to remove meconate of ammonia, and afterwards shaken in ether, or preferably in chloroform, which dissolves out the narcotin, and leaves the morphin in a state of purity. It is now carefully dried and weighed.

THIBOUMERY extracts the weighed sample of opium repeatedly with water, filters the liquors, mixes, evaporates to a thick sirup, and redissolves in water. A large excess of ammonia is added to the boiling solution, which is allowed to cool, and then filtered. The precipitate collected on the filter is now thoroughly washed with cold water, and dried. It is next boiled in alcohol, specific gravity 0.84, and acetic acid is added drop by drop until the liquid turns red. It is now filtered, and the filtrate is again precipitated with ammonia. The precipitate is pure morphin.

To detect minute quantities of opium, if mixed with other substances, the body to be tested is treated with a little potassa, and well shaken with ether. A piece of bibulous paper is dipped several times in the ethereal solution, and allowed to dry between each immersion. It is then moistened with dilute hydrochloric acid, and exposed to the steam of boiling water, when it acquires a red color, more or less intense, according to the quantity of opium present.

PHYSIOLOGICAL EFFECTS.—Opium is used medicinally as a narcotic, sedative, and anodyne, but it usually acts first as a stimulant, and the sedative and narcotic effects are apparently the subsequent collapse of the system. When it excites, the first symptoms are heat, thirst, absence of mind, and sometimes headache and

vertigo, afterwards exhilaration of mind, which ends in sleep, attended often by the most wonderful and agreeable dreams. On awaking, languor and nausea succeed. In Turkey, Persia, and China it is generally employed as a source of pleasurable excitement, and even in this country the habit of opium-eating appears to be on the increase. The habitual indulgence in this drug brings on the most abject debility and prostration of mind and body. In large doses it produces giddiness, stupor, delirium, convulsions, and death. Upon the lower animals, opium and its various preparations have a less marked action than upon man. Thus an ape has been known to take five hundred grains of morphin in a month, or nearly seventeen grains per day, while one-eighth of a grain is as much as can be safely administered to a man in a single dose. To young children opium, in every form, is peculiarly injurious.

It is far from being thoroughly ascertained upon which of the constituents of opium its physiological action principally depends. Morphin is powerfully narcotic and sedative, but does not appear to produce the excitement derived from the use of natural opium. Codein is said by some to produce a calm and gentle sleep, which does not leave behind the dull headache that generally follows after the use of morphin. Others state that it causes violent excitement and intoxication. Narcotin is generally considered inert, though MAJENDIE maintains that it is very active when dissolved in oil. Meconic acid and the soluble meconates were at one time considered to be the active ingredient of the Manna of St. Nicholas, used as a slow poison in the middle ages; but this view is not supported by more recent observations.

In cases of poisoning with opium, or its alkaloids, the peculiar nature of the symptoms observed before death will generally lead inquiry in the right direction. If evidence on this head is wanting, it is necessary to shred the stomach, intestines, liver, *et cetera*, with their contents, and add to every one hundred parts, twelve parts of anhydrous lime or baryta; pound the whole well in a mortar; heat to 212°, and pulverize the mass most thoroughly. The powder is now three times exhausted with boiling absolute alcohol, and the liquid filtered after cooling. The bodies sought for are thus obtained, contaminated merely with fatty or resinous matters. Evaporate now carefully to dryness, and treat the dry residue with ether, to remove fatty matters. Morphin, if present, will remain undissolved, and may be filtered off and recognized by the usual tests. Codein, narcotin, and papaverin will be dissolved by the ether; add acetic acid, and precipitate with ammonia.

OXALIC ACID.—*Acide oxalique*, *Acide carbonex*, French; *Kleesiure*, *Oxalsiure*, German.—This acid was obtained by SAVARY, 1773, and WIEGLER, 1779, from the salt of sorrel or binoxalate of potassa, and by BERGMANN from the action of nitric acid upon sugar, but its constitution was first pointed out by SCHEELE.

It exists naturally, combined with potassa, soda, or lime, in a great variety of plants, especially *oxalis acetosella* and *corniculata*, *Rumex acetosella* and *acetosa*, also in guano, in certain urinary sediments and calculi,

and combined with protoxide of iron, *Humboldtite*, in beds of brown coal.

It is generated by the action of nitric acid upon vegetal matter, especially upon substances containing no nitrogen—such as starch, gum, lignin, washed sawdust, and most advantageously, sugar or treacle. It is formed also when cyanogen is decomposed by water, or uric acid by chlorine, or the peroxides of lead and manganese; when organic substances are treated with caustic alkali in large excess; and during the preparation of potassium from carbonate of potassa and charcoal.

PROPERTIES.—Oxalic acid, in its ordinary crystalline state, forms large transparent colorless prisms belonging to the oblique system; specific gravity 1.641; inodorous, but intensely sour. It dissolves, if pure, in eight parts of water at 60°, but in two parts if contaminated with nitric acid. Boiling water dissolves its own weight. The crystals usually give out a sharp crackling sound during solution. It dissolves also in four parts of alcohol, and in sulphuric and hydrochloric acids, without decomposition, at ordinary temperatures.

The crystals, if heated in the air, lose two equivalents of water, and form a white, effloresced, powdery mass, which, at about 200°, sublimes, and is deposited upon cold surfaces as transparent, colorless, hard, slender needles. The so-called dry oxalic acid is composed of C_2O_3 , $HO = 45$. Some chemists are of the opinion that its equivalent ought to be doubled, thus: $C_4H_2O_3$ or $C_4O_6 + 2HO = 90$. The radical theory assumes the existence of a hypothetical anhydrous acid, $C_2O_3 = 36$, of which the ordinary dry acid is then regarded as a hydrate, HO, C_2O_3 . Oxalic acid is sometimes represented in chemical formulæ by the symbol, \bar{O} or Ox .

This is one of the most powerful acids. When dissolved in two thousand parts of water it still reddens litmus. At boiling temperatures, in the moist way, it expels most other acids from their combinations; a fact which depends in part on its fixity, and in part on the insolubility of most of its salts. Thus it decomposes not only carbonates, nitrates, chlorides, but chromates, phosphates, and even some sulphates and fluorides.

Oxalic acid is decomposed if passed through a red hot tube, if treated with chlorine or bromine gas, or if heated with nitric, iodic, sulphuric, phosphoric, chromic, and vanadic acids, or if treated with the peroxides of lead and manganese. In contact with the chlorides of gold and platinum, it is decomposed under the influence of light, the metal being precipitated, and carbonic acid gas evolved. The reaction with salts of gold may be advantageously applied for estimating the amount of oxalic acid present in any of its compounds. The substance in question is dissolved in water if practicable, otherwise in a little hydrochloric acid, and water added in excess. A solution of the auro-chloride of sodium is then added, the liquid boiled for some time, solar light being excluded, the precipitate of reduced metallic gold is allowed to subside, filtered off, washed, dried, ignited, and weighed. One equivalent of gold represents three equivalents of oxalic acid.

MANUFACTURE.—The manufacture of oxalic acid is very simple. Brown sugar or treacle is submitted to the action of nitric acid. The starch-sugar obtained from potatoes or horse chestnuts may be likewise employed.

For this purpose clean potatoes or horse chestnuts, the latter previously freed from their husks, are ground to a pulp, which is then repeatedly washed with water. The mass thus purified is mixed with sulphuric acid to the extent of about two per cent. of the original weight of the potatoes, and a sufficient quantity of water to reduce it to a tolerably fluid pulp. The whole is then run into a leaden tank, and boiled by means of steam pipes passing through the vessel. This operation is continued for some hours until a drop of the liquid, when taken out, is no longer turned of a bluish color on the addition of iodine. The whole is then strained through a horse-hair cloth, and the clear liquid evaporated down at a steam heat, until it has a specific gravity of 1.75, or until a gallon weighs about fourteen pounds. It is now ready for use.

In the conversion of sugar or sirup into oxalic acid, one may use either vessels of earthenware or wooden tanks lined with lead. The former are generally made to hold about two gallons each, and are set in large numbers in a stout water-bath built of brickwork, which is lined with lead or cement, and heated by coils of steam-piping. The wooden tanks are generally about eight feet square by three feet deep, each being heated by about forty-eight feet of one-inch steam-pipe. They should be provided with large taps placed at the bottom to draw off the liquor into the crystallizing pans.

The vessels are now charged with the sugar or sirup, and nitric acid is added. The usual proportions are—to every hundredweight of sugar as much nitric acid as can be obtained from five hundredweight of nitrate of potassa, and two and a half or about three hundredweight of sulphuric acid. The nitric acid should have a specific gravity of from 1.200 to 1.270. If a more concentrated acid is employed great loss is occasioned, since a large part of the sugar is then converted, not into oxalic, but into carbonic acid. The tanks are then heated to about 125°. If the operation is properly managed, there will be a moderate, steady, disengagement of gas, and a very faint smell of nitric oxide, but no appearance of orange fumes. A slight addition of sulphuric acid is generally considered advantageous. When the operation is at an end, the liquid is let off into shallow cooling tanks, which are also made of wood, and lined with lead, and is there allowed to crystallize. The mother liquor is run off from the crystals, and added to the materials in the next operation. The crystals are carefully drained, washed, dried in a stove, and, if necessary, redissolved and recrystallized. The yield is variously stated; one hundredweight of good brown sugar affording, according to some, fifty to sixty pounds; according to others, one hundred and forty pounds of acid. If, however, the process is properly conducted, and the crystals freed from moisture and nitric acid, the result will be about one hundred and twenty-five pounds. Treacle, if of good quality, gives about one hundred and six pounds per hundredweight.

OXALATES.—The salts of oxalic acid are either *normal*, of the composition, C_2O_4M —where M represents any metal—*acid*, C_2O_4M , C_2O_4H , *hyperacid*, C_2O_4M , $3C_2O_4H$, or *basic*. Alkaline normal oxalates are reduced

on ignition out of contact with the atmosphere to carbonates, carbonic oxide gas being evolved. Oxalates of the heavy metals yield either pure metal and carbonic acid gas—copper, mercury, platinum, silver—or oxide, and a mixture of carbonic acid and carbonic oxide gases—iron, manganese, *et cetera*. Most normal oxalates are insoluble in water, but dissolve in dilute nitric acid.

The most important of the salts of oxalic acid are the oxalate of ammonia—formed by neutralizing ammonia or its carbonate with oxalic acid—and the acid oxalate of potassa—*salt of sorrel* or *sal acetoselle*— $C_2O_4K + C_2O_4H + 2Aq$. The former is used in the laboratory for detecting and determining lime; the latter is prepared by neutralizing a given quantity of oxalic acid with carbonate of potassa, and then adding as much more acid, or by pressing the leaves and stalks of the *oxalis* species, concentrating the clarified juice to crystallization, and recrystallizing so as to get rid of impurities. It forms oblique prismatic crystals, which are persistent in the air, and soluble in fourteen parts of boiling water. This salt is employed for the same purposes as the free acid. A hyperacid salt, or quadroxalate, of the constitution $C_2O_4K, 3C_2O_4H$, is sometimes found in the market along with, or instead of, the preceding.

Oxalate of lime is a white powder, formed whenever oxalic acid, or one of its soluble salts, is added to a calcareous solution. It is also found in a crystallized state in animal and vegetal tissues. It is insoluble in water, solution of chloride of ammonia, or acetic acid, but dissolves readily in dilute nitric or hydrochloric acid, and is decomposed on prolonged boiling with soluble salts of lead, copper, silver, cadmium, zinc, nickel, cobalt, strontia, or baryta.

ESTIMATION.—Oxalic acid may be very readily detected by adding to its solution, which, if acid should be previously neutralized with ammonia, a solution of sulphate of lime. A white cloud is produced in a few minutes.

The amount of oxalic acid in any substance may be determined either by the process with one of the salts of gold as described above, or from the carbonic acid given off on decomposition of the oxalic acid in contact with sulphuric acid and peroxide of manganese. A weighed portion of the oxalate to be examined, or of the free acid, which must be subsequently dissolved in water, and slightly supersaturated with ammonia, is placed in the larger flask of FRESSENIUS and WILLS' alkalimetric apparatus, along with an excess of finely-powdered peroxide of manganese, freed previously from carbonates by lixiviation with dilute hydrochloric acid. Water is added until one-third of the flask is filled. The other flask is then charged with sulphuric acid, and the operation is conducted exactly as in the examination of a sample of alkali. When the process is at an end, which is shown by a total cessation of the evolution of gas, even though a fresh portion of sulphuric acid is sucked over, the apparatus is weighed, and the loss determined. Every twenty-two grains of carbonic acid lost, represent twenty-three grains of oxalic acid present in the sample. This method is capable of great precision, but requires, of course, a sensitive balance.

PATENTS.—A great object with manufacturers of oxalic acid is to economize nitric acid, by reoxidizing the nitric oxide given off in the process. To this the carbonic acid, which is always simultaneously generated, proves an obstacle. JULLION'S method, patented in 1846, is as follows:—The materials are placed in a so called *generating vessel*, holding about a hundred gallons. This vessel resembles a Woulfe's bottle, provided with a movable top fitting air-tight. It is heated by a water bath, or a steam jacket. The nitric acid is then introduced, and a current of air, or of oxygen gas, driven in through a pipe passing through one of the apertures in the top. The nitric oxide given off by coming in contact with the oxygen is partly converted into nitrous acid and peroxide of nitrogen, which are reabsorbed by the liquid in the generating vessel. The rest is led off by a pipe issuing from another hole in the top, which traverses a furnace where it is enlarged, and heated to 600° – 900° . Here it is charged with spongy platinum, in contact with which all the lower oxides of nitrogen are converted into nitric acid, which is then condensed in the usual manner.

In CRANE and JULLION'S *continuous process*, a covered vessel constructed of slate, and termed a *generator* is charged with mother liquor from a former operation. Above the generator are placed two feeding vessels containing respectively sirup and nitric acid in suitable proportions. The liquor in the generator is then raised to about 180° or 200° , and the nitric acid and sirup allowed gradually to flow in by means of stop-cocks, so that the delivery of the whole may take eighteen hours, by which time the operation is at an end.

Meantime the gases given off from the decomposing sugar or sirup are carried off through a vent pipe issuing from the top of the generator into another vessel containing water. Here it meets with a stream of chlorine gas which decomposes the water, forming a mixture of nitric and hydrochloric acid vapors, which are received and condensed in suitable vessels.

In MACDOUGAL and RAWSON'S patent process, the gases given off from the generating vessel are drawn by an air pump through a set of Woulfe's bottles containing water, into which air is also admitted. In this manner nearly the whole of the nitric oxide is said to be reconverted into nitric acid.

ECARNOT passes his gases mixed with a current of steam from a boiler, and with air supplied by a blast over surfaces of pumice-stone.

A variety of other processes for the manufacture of oxalic acid have been suggested, one of which, patented by Dr. WILTON TURNER, is certainly a curiosity, as it, like other absurd patent methods, involves the use of a material *much rarer and more expensive than oxalic acid itself*. He operates upon uric acid obtained from guano. This is to be boiled with water in which peroxide of lead or manganese is suspended. If lead is to be employed, a known weight of uric acid is put in an open iron cylinder sufficiently large to hold a quart of water for every pound of uric acid employed. Clear lime water is added, and the whole is made to boil briskly by a steam heat. Peroxide of lead is then added gradually, as long as it is

observed to be whitened by the liquid. About one hundred and sixty pounds of peroxide are required for every hundredweight of uric acid. The clear liquor is run off, the white sediment of oxalate of lead is washed and boiled with dilute hydrochloric acid. Chloride of lead remains as a precipitate, whilst oxalic acid crystallizes out of the solution. Another product of treating the uric acid with peroxide of lead is *allantoin*, which is converted into oxalic acid and ammonia by boiling with caustic potassa. The ammonia escapes, and may be condensed and collected in a suitable apparatus, whilst the oxalic acid is obtained as oxalate of potassa. The urea generated in this process appears to be wasted.

Uses.—Oxalic acid is employed principally as a discharging agent in certain styles of calico printing, for whitening leather, as for boot tops, and for removing ink and iron-mould from wood and linen. Its acid potassa salt, which serves for the same purpose, is sometimes most reprehensibly sold as *salt of lemons*, a practice which might easily occasion fatal accidents.

Oxalic acid, if taken internally to the extent of half an ounce or upwards, acts as a violent corrosive poison. The remedy is of course chalk, or any other form in which carbonate of lime is most accessible.

PAPER.—*Papier*, French and German; *Papyrus*, Latin.—Mankind have, in all ages and circumstances, except when sunk in the lowest state of barbarism, evinced a strong desire to transmit to posterity a record of their transactions, or something that would be a memorial of their existence and achievements. This principle is inherent in human nature, and has been implanted for the most beneficent ends. Without it the advantages to be derived from a knowledge of the experience and wisdom, as well as the crimes and follies, of preceding generations, would have been lost to posterity, and the history of the past could only have been gleaned from an obscure and uncertain tradition. To gratify this natural desire of living in future ages, men have resorted to various expedients. In the primitive ages they were satisfied with a stone, or a heap of stones, as a memorial of some important transaction; but when population became more dense, and more regular forms of government were established, huge structures were erected, which must have cost an almost inconceivable amount of labour and suffering, and of which the early architecture of Egypt affords the most remarkable example. Subsequently these structures were covered with hieroglyphies, and finally, the same object was more concisely accomplished by the art of writing, which was known at a very early period. The substances used for writing upon in primitive times were first stones and bricks, and afterwards leaves and the bark of trees. Besides these, lead, copper, wax, and wood, were also employed; in fact, almost everything that presented a smooth surface on which inscriptions could be made. Books are said to be in existence, the leaves of which are thin sheets of lead. Linen had also been used at a very early period, as is evidenced by the inscriptions upon the bandages of some of the most ancient Egyptian mummies. At a later date skins and the entrails of animals, and even bones, were applied to the same purpose.

PAPYRUS.—The material which eventually came

into general use, and nearly superseded all others, was the *Papyrus* of Egypt. It was made, as is generally known, from a reed or plant of the same name, which grew in marshy places, and along the banks of the river Nile. It is said to have grown in situations where the water was stagnant and only a few feet deep. At what time it came into use is uncertain. There is reason to believe, however, that its application as a writing material may be dated one thousand years before CHRIST. The prophet ISAIAH speaks of the paper reeds of Egypt as well known, and he lived nearly eight centuries before the Savior. The papyrus was undoubtedly the principal writing material which mankind possessed for many hundred years. As such it was highly valued and extensively used, and has transmitted its name to the material now universally employed. PLINY's account of the mode of preparing it is as follows:—The papyrus, says this writer, was cut before reaching maturity, being then in a soft and spongy state, and was divided by a peculiar needle into thin plates or pellicles, which were laid lengthways on a table alongside of each other, with their edges touching. Another layer was laid across at right angles. These were moistened with warm water and then pressed, which caused them to adhere, so that the two layers became one compact sheet.

It was believed that the water of the Nile possessed a gummy property, causing the layers to adhere in this manner. But BRUCE, the celebrated traveller, denies this, and affirms that while in Egypt he partly succeeded in making paper from the papyrus. He states that the plant contains a large quantity of saccharine matter, which warm water dissolves, and this being brought to the surface by pressure, acts as a glue or size. After it was pressed it was dried in the sun, and was then steeped in a size or starch, made by pouring boiling water on bread and filtering the liquor through a cloth, after which the leaves were again dried in the sun. The finer kinds used for writing are supposed to have been made from the inner part of the stem, while the coarser were made from the outer rind, and were used for packing.

There is some difference of opinion among writers in regard to this account; but the Editor conceives that the process may be explained by supposing, not that the reeds were cut into shreds or thin slices, but that, being composed of coats or layers, they were cut or slit up lengthways, and the successive laminae were easily stripped off one after another. Being in a soft and spongy state, they were fragile; and to render the process of stripping easier, the reeds were probably cut into lengths of ten or fifteen inches. The laminae being too weak singly to undergo the process of preparation were laid one over another and then pressed, which would greatly add to the strength of the article so prepared. When Rome attained universal empire, large quantities were carried thither; and there it underwent a higher degree of finishing, being steeped in a stronger size, dried, beaten with mallets, and smoothed with ivory. By these operations a high polish was given to its surface, rendering it probably equal in that respect to the modern enamelled, or at least glazed paper. The article so finished was cut

into a variety of sizes, but none exceeding two feet in length. Alexandria became the chief emporium of this manufacture. In that celebrated seat of learning it was carried on very extensively, gave employment to a great number of people, and was a most important branch of commerce. Towards the end of the Roman Republic the consumption of papyrus was very great, and it increased considerably during the reign of AUGUSTUS. The demand for it by other nations was also so considerable as sometimes to occasion a scarcity of it at Rome. A popular tumult which occurred there during the reign of TIBERIUS was said to have arisen from this cause. The manufacture probably reached its highest point of prosperity during the peaceful reigns of the ANTONINES; but the article continued for a long time in great demand, and the profit derived from it must have been very considerable. GIBBON, in his *Decline and Fall of the Roman Empire*, tells of one FIRMUS, a wealthy merchant of Egypt, who, taking advantage of the Emperor AURELIAN'S war with Zenobia, raised the standard of revolt, assumed the Imperial purple, and, having obtained possession of Alexandria, boasted that he could maintain his army from the profits of the paper trade alone.

In evidence of the extensive use and admirable fitness of the papyrus as a writing medium, it may be mentioned, that eighteen hundred manuscripts of that material have been taken from the ruins of Herculaneum; that a manuscript in the British Museum, which appears to have been written about the year 572, measures eight and a half feet in length; and that one in Paris measures thirty feet. It appears to have been preserved in the form both of books and manuscripts. When bound in a book, a leaf of parchment was inserted between every five leaves; when kept as a manuscript it was in the form of a roll, which varied in length according to the number of sheets pasted together.

Under the Roman Empire paper or papyrus was loaded with a heavy tax, which seems to have been generally regarded as burdensome; for when THEODORIC, king of the Goths, abolished the tax, about the beginning of the seventh century, CASSIODORUS, a historian of that period, congratulates *the whole world on the removal of an impost on an article so essentially necessary to mankind*. It is somewhat remarkable that the British Government is the only one which, in modern times, has continued to follow the example of the Romans in levying this impost; and it is still more surprising that the ruler of a people whom it is the custom to associate with all that is rude and barbarous, should have set an example of enlightenment in dark and troublous times, which even the government of Great Britain, with all its boasted liberality, has not yet imitated. Fortunately, however, a resolution has at length been adopted in the imperial legislature, affirming the inexpediency of the tax on paper, and it cannot be doubted that the days of this barbarous and most impolitic impost are now numbered.

PARCHMENT.—Parchment is another substance which was much used in early times. It is made chiefly from the skins of sheep and goats, and is said to have been invented by EUMENES, a king of Pergamus, who reigned

about two hundred years before CHRIST. It is related that this monarch resolved to collect a library which would equal or excel the famous one of Alexandria; and this so offended PTOLEMY king of Egypt, that he prohibited the exportation of papyrus. EUMENES would not, however, be diverted from his purpose, and he, therefore, had recourse to the skins of animals, the manufacture of which he so much improved as to be termed the inventor of the material. Hence the word *parchment*, from *Pergamus*. At the same time, it is certain that the skins of animals, though less perfectly prepared, were used long before the time of EUMENES, and are spoken of as being employed among the Ionians more than four hundred years before the Christian era.

LEAVES.—The leaves of some kinds of plants, after undergoing a process of drying and rubbing, make a tolerable kind of writing material. Mr. HERKING says that the natives of India use them in preference to paper for ordinary correspondence, and even in important matters. This may arise from a strong attachment to old customs, and not from any alleged superiority in the material. So lately as fifty years ago a Persian manuscript was in existence, supposed to have been written on some kind of leaves.

The substances above enumerated were all used for writing upon; but, however suitable for that purpose, they were altogether useless for printing. The papyrus was too hard and brittle either to receive an impression, or to undergo heavy pressure. The mode of writing upon it, which was with a style or sharp metallic point, shows that it was not suitable to be printed upon. It is, therefore, by no means wonderful that printing was not discovered in the earlier ages of the world.

The relics of Assyrian art which have lately been brought to light, show that the Assyrians had really discovered the art of printing, as far as their materials would admit; and their progress in that direction seems to have been stopped, rather from want of suitable means than by any deficiency of ingenuity. The impression of the foot on sand might, to an observing mind, suggest the idea of printing, as that of weaving might be suggested by the web of the spider. But in the operations of nature, so far as they are open to ordinary observation, there is nothing analogous to papermaking; and indeed it is difficult to understand how any person could conceive the idea of reducing a vegetal to a liquid fibre, for the purpose of obtaining by deposit a thin smooth flexible sheet of considerable strength, and calculated to receive a permanent impression either by writing or printing.

PAPER.—The substances hitherto mentioned have all been natural productions. The labor required to fit them for their intended use, was preparation rather than manufacture, and did not affect their texture. With paper of modern manufacture the case is totally different; its only similarity to leaves and the papyrus consists in its being composed of vegetal matter. In commencing a short historical notice and description of this manufacture, it will be necessary first to define what really constitutes paper.

It is a universally admitted axiom that the meaning of any word is determined by the sense in which it has

long been used. According to this rule, the substance now called *paper* is an aqueous deposit of any vegetal fibre, radically different in its structure from all bodies formerly used for writing upon, being a highly artificial material, and having no resemblance in its texture to any natural substance. A sheet of paper should be of equal thickness throughout, so porous as to admit of an indelible impression, and yet so compact as to undergo without injury almost any pressure. The surface should be so smooth as to be easily written upon, and the sheet so flexible as to fold without cracking. It may be of any *color*, and of any *length*; but seven feet is the greatest *width* to which it has yet been extended.

HISTORICAL NOTICE.—Very little information can now be obtained of the invention and early progress of the art of papermaking. The earliest accounts do not agree either in regard to date or place; but all point to the East as the seat of the discovery, leaving almost no doubt that the principle of the modern art of reducing vegetal fibre to a liquid state is a Chinese invention, dating from about the beginning of the Christian era. A detailed notice of the mode of manufacture supposed to be practised by the Chinese, is given in the *Encyclopædia Britannica*; but, besides that the accuracy of this account may be doubted, the process involves an amount of labor which would render it impracticable in Europe. A great variety of materials appear to be used, all of them vegetal substances reduced to a liquid fibre. The paper produced resembles what is commonly termed *flimsy*, but takes a finer and more delicate impression from copper plates, and is known by the name of *india proofs*. A small quantity of it is used in this country for the finest engravings. It is generally made of the inner bark of the bamboo and cotton tree.

The first accounts of paper bearing any resemblance to the article now manufactured, date from the beginning of the tenth century. It is generally supposed, says the writer in the *Encyclopædia Britannica*, that the paper called *charta bombycina*, which was invented in Greece, supplanted the Egyptian papyrus, and this paper is incomparably more lasting, and better calculated for all the purposes of writing. It is not precisely known at what period this art, which supposes a great variety of experiments, was first reduced to practice. Whether or not the Greek mode of making paper was imported from China it is now impossible to determine. Some accounts state, that paper was brought by the Arabs to Mecca in the eighth century, along with a knowledge of the art, and by the end of the ninth century they had carried it to the coasts of Barbary and Spain. GIBBON says, that the knowledge of the inestimable art of making paper from linen rags was diffused from the manufactures of Samarcand over the Western world; and in a foot-note he adds, that the librarian CASSIRE relates from credible testimony that paper was first invented, or rather introduced, at Mecca by JOSEPH AMRU, in the year 706 or 710. The Escorial library contains a manuscript on paper of this kind as early as the tenth century. There is little information of the progress of the art during the three following centuries, or even until the beginning of the fourteenth. From an American work,

The Chronology of Papermaking, it appears that in the year 1085 the Christian disciples of the Moors worked the paper-mills at Toledo in Spain to better advantage than their predecessors, and that instead of cotton they used rags, and made the paper with moulds. From the time, however, that paper was manufactured from fibre, moulds or sieves must have been used; and this probably refers, therefore, only to some important improvement which was effected upon them. It is stated in the same work that in the year 1151 the best paper was made at Xativa from rags. At this date also occurs the first notice of water-mills and the use of mallets. But from the disorganized state of society in Europe during this period, it could hardly be expected that an art like papermaking, which even in its simplest form requires an outlay of considerable capital, could make much progress.

The art reappears in Germany towards the end of the fourteenth century; but it is stated that even from the beginning of that century paper-mills were in operation in Tuscany. A mill was erected at Nuremberg in Germany to make paper from linen rags, by ULLMAN STROMER. At this time the process was kept strictly secret, and the workmen were sworn not to divulge it or carry it on on their own account. Notwithstanding all these precautions to keep the art secret, it became known, and was introduced into France, Holland, and Genoa, in all of which it seems to have been prosecuted with considerable success, particularly in France, whence there was a considerable quantity exported to Britain and other countries. The trade began to decline in France about the middle of last century, as other countries, particularly Britain, were by that time manufacturing nearly sufficient for their own use.

The first paper-mill in England, of which there is any particular account, was erected at Dartford in Kent in 1558, by Sir JOHN SPIELMAN, a German jeweller in the employment of Queen ELIZABETH, who, for services rendered in this respect, bestowed upon him the honor of knighthood, and gave him a license for the sole gathering of rags for ten years. Mr. HERRING says, it is quite certain that paper-mills were in existence long before SPIELMAN's time, and adduces a passage in SHAKESPEARE's play of *Henry the Sixth*, in which reference is made to a paper-mill at least a century before this; but he admits that the chronological accuracy of SHAKESPEARE is not to be depended on, and that the earliest traces of the manufacture in this country occur in a book published by CAXTON in 1490. The mill to which reference is supposed to be made, was near Stevenage in Hertfordshire. In the household book of HENRY the Seventh, there is an entry of a reward of sixteen shillings and eightpence given to the *paper mylne*, dated 25th May, 1498; and again in 1499 another reward of six shillings and eightpence is given to *Tate of the Mylne*, supposed to be the mill at Stevenage.

In Scotland the manufacture is of still more recent date. The first paper-mill, according to current accounts, was erected at Netherlee, near Glasgow, by a Dutch papermaker. The calamities which befell Scotland during the reigns of the last three STUARTS

prevented the introduction and development of manufactures; but after the Revolution, when protection was afforded to life and property, papermaking, like other manufactures, began to revive.

The French protestants who fled to England for refuge from the persecution which followed the revocation of the edict of Nantes in 1685, are said to have introduced many improvements into the paper manufacture. About this time white paper, of which little had been made, began to be more generally manufactured, and the quantity rapidly increased. It was estimated that about three hundred thousand reams were produced in 1721, and this was supposed to be about two-thirds of the consumption of the country.

MATERIALS FROM WHICH PAPER IS MADE.—The materials of which paper is manufactured are vegetal substances containing fibre, and are not so limited in number and kind as is commonly supposed. Linen and cotton rags, affording the greatest facilities of manufacture, have most generally been used, and are nearly all made into white paper. The rag merchant packs them according to their quality, and when brought to the mill they are cut, and assorted more perfectly. A large quantity of the rags used in this country are imported, and are principally of linen.

Ropes and the sweepings of cotton-mills, called *cotton waste*, furnish a large supply of material for papermaking. Incongruous as these may appear, they are generally used together, and when properly prepared make a beautiful paper, but require a great amount of labor. *Wrapping paper*, for which great strength is the most important requisite, is generally made from these materials; and they can be used for that purpose with comparatively little labor. But the American makers are in advance of the British in the use of these stuffs. By a peculiar process of cutting, cleaning, and boiling, Mr. H. V. BUTLER of New Jersey has succeeded in making from them the best printing papers which the Editor has yet seen. The sweepings of flax-mills, called *flax waste*, are very useful in making strong wrapping paper, where beauty of appearance is not an object, and furnish a considerable supply to the manufacturer. The best kinds can be used for white paper, but require much labor in preparation. Jute, surat, or nettle bagging, all of which appear to be substances of a similar kind, are now extensively used in making colored and brown papers. They are grown in India, and are made into bags, in which form they are imported into this country.

Straw.—Chemical science has also introduced straw—chiefly that of wheat—into the category of materials used for papermaking. When intended for printing papers, it requires to be boiled in a strong lie, to destroy the silica it contains. The fibre is short and tender, and not calculated to make of itself a good paper. It is, however, improved by being mixed with a stronger substance. Although it is only lately that straw has been successfully used for this purpose, yet as early as 1756 an attempt was made to manufacture paper from it in Germany, and in 1800 the Marquis of SALISBURY presented a book to the king printed on paper made from straw. In 1812 a Frenchman announced a new method, so simple that any person

could make paper from this material in a manner equal to the best workman, and in 1820 M. HUYGERON, another Frenchman, obtained a patent in France for a similar process. In 1828, WILLIAM MAGAW of Chambersburg, U.S., took out a patent for making paper from straw and blue grass. In 1854, M. KELIN of Belgium invented a process for converting straw into paper, which differed from any other in use. The straw was steeped in water sixty hours, when the liquid was run off and the straw washed with a plentiful supply of water. It was then passed between two rollers in a damp state, and afterwards cut into fibres of suitable length, and exposed to the bleaching effect of the sun's rays. It was now submitted to another bleaching process of three or four days, and subjected to the action of a solution of chloroxide of sodium or potassium, until it acquired a sufficient degree of whiteness, when it was put into the engine.

In 1857 another new mode of preparing straw was said to be discovered, but is not yet made public.

Wood.—The linden tree or bass wood affords another material for making paper, and several mills in the United States are at present employed in manufacturing it from this substance. The first attempt to apply it seems to have been made in France in 1776. Other kinds of timber have also been used; and in 1836 R. and J. C. MARTIN secured a patent for obtaining a pulp from wood, by first saturating with water planks or chips, then subjecting their surfaces to a cylinder having teeth resembling a saw or rasp, by which the ligneous fibre was reduced to a pulp. sanguine hopes were at one time entertained that this plan would prove successful, but the Editor has not heard of its having been seriously adopted by any papermaker. It is difficult to reduce wood to a fibrous liquid, as the fibre is short and weak; and no means have yet been discovered of converting it into a pulp of the requisite fineness without, at the same time, reducing it to powder. If pine wood could be sufficiently bleached and pulverized, a portion of it might be used among pulp with advantage, as the resin it contains would improve the size.

Animal and other Substances.—Several attempts have also been made to fabricate paper, either wholly or in part, from animal substances, but hitherto with little success. Chamois leather, when properly prepared, and a portion of it mixed with pulp, makes a strong tough paper, but of a poor color. The machinery for preparing rags is unsuited for animal substances, its effect being to tear out, while animal materials require to be bruised or rubbed. Paper from such materials was lately manufactured at a mill in England, and was expected to be free of duty, but the case was otherwise decided.

From this enumeration it will be seen, that the field from which the papermaker can draw his raw material is not so confined as has been supposed; and these are but a portion of the substances which have been proposed and experimented upon. Mr. HERRING remarks that the fibre of vegetals which is capable of being made into paper may generally be first manufactured into some other fabric, such as cloth, ropes, or mats, and after it has served its purpose in that form it is then a

fit material for making paper. And in regard to experiments with new substances, he quotes Dr. FORBES ROYLE, who observes, that the generality of modern experimentalists seem totally unacquainted with the labors of their predecessors, many of them commencing improvements by repeating experiments which had been already made, and announcing results as new which had been long previously ascertained. As an evidence of the number of substances which have been tried, this writer refers to a book in the British Museum, printed in Low Dutch, and consisting of upwards of sixty specimens of paper, manufactured from as many different materials, all the result of one man's experiments, and made previous to the year 1772. In point of fact almost every vegetal has been tried. Nettles have always been a favorite article with experimentalists. It is not long since it was announced that hollyhock stalks were to furnish an almost inexhaustible supply for the papermaker. There is no doubt that it is possible to reduce every vegetal to a fibre, and with it to make paper. But notwithstanding all the discoveries of new substances which have been made, and all the protection which patents can afford, it is still found that flax and hemp, or rags, ropes, and other fabrics composed of these substances, constitute the staple materials of the paper manufacturer. And the Editor believes, that until science makes further discoveries in the mode of preparing new substances, papermakers will find it more profitable to abide by the use of the old materials, than rashly to indulge in experiments on their own account.

Supply of Materials.—Judging from the past history of papermaking, there does not seem to be much reason to fear that the present sources from which the paper manufacturer draws his raw material will ever be insufficient to supply the demands of the trade. The fact that it has always been when this manufacture was first introduced into a country that there was any considerable difficulty in obtaining the raw material, and that as the manufacture extended the supply also increased in about the same ratio, would seem to warrant the conclusion, that fears on this subject are groundless, so long as the present sources of supply exist. On the other hand, it must be taken into account that the countries from which the largest quantity of rags is imported are those along the shores of the Baltic and Italy; and were these countries to commence manufacturing for themselves, the supply from them would cease. At the same time, in proportion as civilization extends and population multiplies, new sources will open, and long before an absolute deficiency is felt, science may discover new materials as well as new processes.

The Editor has found some difficulty in reconciling the conflicting statements regarding the importation of rags into this country; but it appears that nearly a seventh part of the raw material is imported. In the year 1853 it was estimated that ninety thousand tons of rags were used in the paper manufactories of Great Britain, of which fifteen thousand tons were imported; but that, taking that year with the two preceding ones, the average annual importation was below ten thousand tons. In that year there was charged with duty, one

hundred and seventy-seven million, eight hundred and thirty-three thousand, and ten pounds of paper, besides about two hundred thousand pounds imported; and thirteen million, two hundred and ninety-six thousand, eight hundred and seventy-four pounds were exported, leaving for home consumption one hundred and sixty-four million, five hundred and thirty-six thousand, one hundred and thirty-six pounds. If, therefore, a seventh part be deducted from the total quantity charged with duty and imported, as representing that which had been made from imported rags, there remains only one hundred and fifty-two million, four hundred and twenty-five thousand, two hundred and ninety-two pounds; or there would have been a deficiency of upwards of eleven million pounds had this country been confined to the home market for its raw material. The discovery, therefore, of some new substance, which would really meet the wants of the paper manufacturer, and which could be provided at a cost not above the present price of rags, would undoubtedly be a national boon.

As these remarks may bring upon the papermaker a multitude of suggestions, and load him with specimens of all sorts of vegetals, from cabbage stalks to lamb-woo branches, the Editor would advise discoverers of new materials for making paper to work out their own suggestions, and first to ascertain the cost at which the proposed materials could be obtained, and also the cost at which they could be made fit substances for the paper manufacturer, before introducing their discoveries to public notice or incurring the expense of a patent.

PREPARATION OF RAGS.—The proper preparation of the rags is an object of great importance to the papermaker, and one which requires both skill and attention. It is, moreover, a subject on which opinions are divided. In these circumstances it will be sufficient to describe the mode of preparing the rags at the most extensive mill in this country, where the best writing and printing papers are manufactured.

Cutting the Rags.—The first process is the cutting of the rags, which is performed by females. Each woman is stationed at a small table about three feet square, and covered with a netting of wire. In the centre of the table a knife, about eighteen inches long and five inches wide, is placed nearly vertical. The woman stands at the back of the knife, and a quantity of rags are given to her, of which she lays a small portion on the table. She then cuts the rags into strips three or four inches wide, taking off buttons, hooks and eyes, *et cetera*, and laying out all substances unsuitable for the making of paper, such as india rubber, and pieces of woollen and silk. At her right hand is a box divided into several compartments, into which she throws the rags according to their qualities. A large quantity of sand falls through the meshes of the wire-cover into a box underneath. All pockets and seams should be ripped up to allow dirt to escape, and to prevent, as far as possible, anything getting among the prepared rags which would be injurious to the paper, or hard substances, such as pieces of iron, which might break the machinery.

The rags are again examined by women called *overhaulers*, or *overlookers*. There is generally one

overhauler to every eight or ten cutters. Some manufacturers attach great importance to having their rags cut into pieces four inches square. But the mere size of the rags is a matter of indifference. The principal object is to have them in a state which will insure their thorough cleansing in future processes, and cause them to float among water in the rag-engine without twisting and warping round the roller. Anything smaller than is necessary for this purpose causes a greater loss of fibre in the willow and duster.

Willowing of Rags.—From the overhaulers the rags are taken to the *willow*, which consists of two cast-iron cylinders, two and a half feet diameter, and three and a half feet wide, covered with iron teeth projecting about four inches. These cylinders are set one behind the other. Below them is placed a semicircular screen, and a cover of the same shape above. This cover is also provided with teeth, and is adjusted so that the teeth in the cylinders pass those in the cover at a distance of a half or three-quarters of an inch. In front are a pair of rollers and a revolving apron, for the purpose of carrying the rags into the cylinders. These revolve with a rapid motion, and the rags, being thrown by the first into the second, are confined in the cylinders about twenty seconds, when a sliding door, which rises three times in one minute, allows them to be discharged into a duster. As often as this sliding door opens, the revolving apron moves forward, and charges the willow with a fresh supply of rags. The latter, being thus beat and teased in the willow, are loosened in the texture, and a large quantity of sand falls through the screen underneath.

The *duster*, into which the rags are discharged after passing through the willow, is a large cylinder twelve feet in length and five or six feet in diameter, which is placed lengthwise against the willow, and revolves slowly at right angles to it. This cylinder is covered with a coarse wire-cloth, and a number of teeth are fixed into it at regular intervals, which toss and shake the rags, thereby removing any remaining dust, which falls through the meshes of the wire-cloth. The rags are now deemed ready for boiling. About five hundredweight of rags are carried through the willow in one hour. Cotton and flax waste is passed two or three times through the willow.

In willowing there is a considerable loss of fibre, particularly when the process is repeated more than once. The willow dust is therefore preserved, and is used in some inferior mills for making wrapping papers.

Boiling.—Rags are boiled in a solution of alkaline lie made of quicklime and soda, generally in the proportion of one pound of lime to two of soda. This caustic alkali is prepared by boiling the lime and soda together. While settling it should be well stirred and mixed, and afterwards allowed to stand for a few hours, until the sediment falls to the bottom, when a clear liquid is obtained. The quicklime is first thrown among the hot water, and some think it improves the lie to introduce the soda immediately, while the lime is slaking, as a high degree of heat is then evolved, which dissolves the soda very quickly. Others slake the lime in a cistern by itself, and after stirring well, allow the heavier and undissolved portion to fall to the

bottom, then run off the upper portion, which has the appearance of a fine thick cream, into another vessel, and afterwards put in the soda. Another method is to dissolve the lime as above, and run it into the boiler among the rags; the quantity of soda to be used is then put into a bag, which is introduced into the boiler and its contents allowed to dissolve. But the general way is to mix the lime and soda, and run the pure liquid into the boiler. For the finest papers this liquid should be quite pure. Six to ten pounds of soda, and three to five of lime, are generally used for one hundredweight of rags; but this proportion varies according to the quality of the rags, and every manufacturer has his own method of procedure.

Rags are boiled for the purpose of *killing*, or destroying, minute particles of the stem of the flax and shell of the cotton, which even very fine cloth contains. These substances, which are generally called *shove*, are very injurious to paper, and boiling is the only way to get rid of them. It also loosens the dirt in the texture of the rags, and considerably improves their color. A strong flax rag will lose from one-third to one-fifth of its weight by boiling and washing.

It is not more than thirty years since papermakers began to boil their rags, and the boiler long used was simply a cast-iron vessel, large enough to contain about ten hundredweight of rags. It had a furnace underneath, and was heated by the direct action of the fire. The chief objection to this mode was, that pieces of rags adhered to the sides of the boiler, and were burned. Steam was then tried, and found to be much cleaner in its operation. Circular, and sometimes square boilers, were adopted. When steam came into use, a perpendicular pipe was inserted into the centre of the boiler, which had a double bottom, the upper one being of movable perforated plates, and raised about nine inches above the lower. The steam was admitted from the top, and passed by the vertical pipe into the space between the bottoms, where it escaped into the boiler by tubes radiating from the central pipe to the sides of the vessel. This is still considered by many manufacturers to be a good boiler. An addition was made to it by some papermakers, who inclosed the steam pipe in a larger one, leaving a space of two or three inches between the two. When the liquid containing the rags was brought to the boiling-point, it was forced up between these pipes; and round the top of the outer one was a large flange, which spread the lie over the surface of the rags. A constant circulation was thus maintained by the rising of the lie in the space between the pipes, and its subsequent descent through the rags contained in the body of the vessel. This is reckoned a good boiler, and is still used by a number of papermakers. It is generally made seven feet in diameter by four deep, from the rim to the false bottom, and will boil ten or twelve hundredweight of rags in twelve or fifteen hours. It is known, from its peculiar action, as the *vomiting boiler*.

The apparatus now in greatest repute is the *revolving boiler*, of which at least three different kinds are made. This form of boiler was first applied by H. V. BUTLER of New Jersey twelve years ago. It is a large iron cylinder revolving horizontally on bearings, and divided

into four compartments with double ends; the inner ends being perforated plates by which the boiler is drained, and provided with a small door, large enough to admit a man, by which the vessel is filled and emptied. This boiler operates with less soda, and the boiling is performed in from eight to ten hours. Revolving boilers were first introduced into England about the year 1854 by BRYAN, DONKIN, and Company, of London, who secured a patent for a boiler on this plan. It consists of two iron cylinders lying horizontally, one within the other. The outer cylinder is stationary, while the inner, which is perforated, is so constructed as to

revolve. There is a frame and rack in front, by which the inner cylinder can be drawn out; two large plates are then taken off and the cylinder turned round, when the rags fall out. The front end is bolted on to the outer case, and keeps the boiler steam-tight. In this apparatus the rags require only from eight to ten hours' boiling, and a small saving of soda is effected.

Another revolving boiler has been patented by Mr. JOHN ROBERTSON, engineer to Messrs. A. COWAN and SONS, Valleyfield, near Edinburgh. This apparatus is represented in Figs. 379 and 380. It consists of two cylinders; the outer one, A, is made of boiler-plate,

Fig. 379.

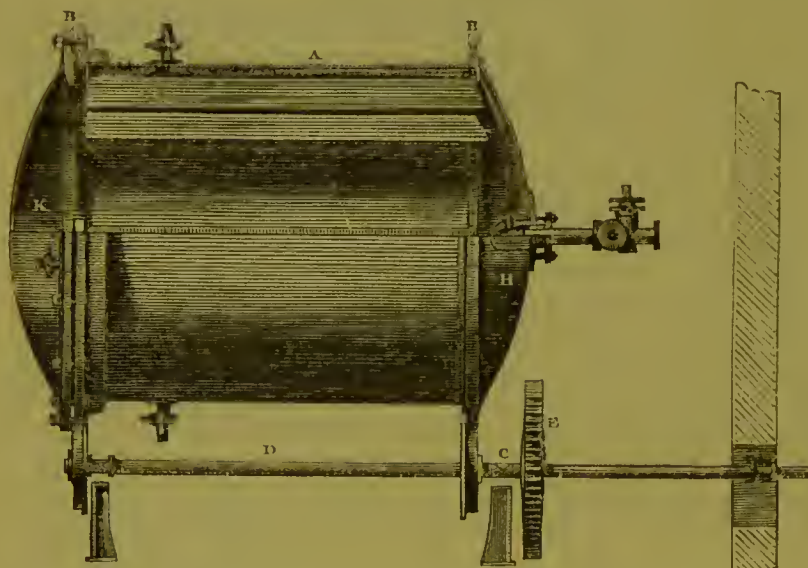


Fig. 380.



and is rivetted to cast-iron flanges, B, which revolve slowly on four friction wheels, C, fixed on two shafts, D, with spur wheels, E, on one end of them for receiving a motion. The inside cylinder is formed of perforated iron plates, with bars or shelves, FF, projecting inwards, for the purpose of agitating the rags. The steam and lie are admitted through the centre of the back end, H, of the boiler, in pipes, G G, leading to the space between the two cylinders. The rags are put in and taken out by removing the other end, K, of the boiler, which end or door is also made of boiler-plate, and is rivetted to a cast-iron flange with a turned face, fitting into a corresponding groove in the flange on the body of the boiler, and secured by strong bolts, making a steam-tight joint. This boiler is calculated to stand a pressure of sixty pounds per square inch, thereby subjecting the rags to a higher temperature than that of boiling water.

An opinion prevails that a high degree of heat is beneficial in boiling rags—that by using high-pressure steam a smaller quantity of soda is required—while by having the boilers steam-tight this high pressure is kept up with a small expenditure of steam. In practice it has been found that, while boilers constructed on this principle effect a considerable economy of time, there is no great saving of alkali, and that a small escape of steam is positively beneficial.

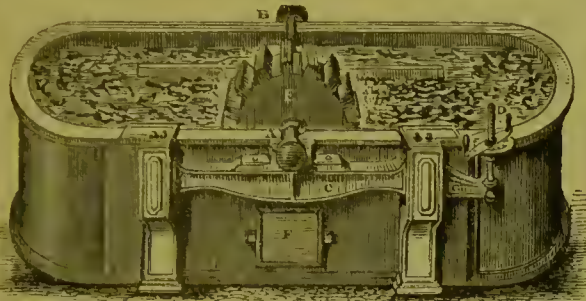
A different system of boiling has been patented by Messrs. CRANSTON and LOVELL of Chirnside. Their apparatus consists of a series of oval stationary boilers,

each containing about seven hundredweight of rags. These are likewise heated with high-pressure steam, which passes from one to another; and the boilers being steam-tight, only a small quantity of steam is required, while a saving of alkali is also effected. The Editor believes this mode of boiling has given satisfaction to those who have adopted it. Strong and perfect boiling is a highly important point in papermaking, and contributes greatly to the production of a clean and pure article. Any defect in this operation can never be remedied by subsequent processes.

Washing Engine.—The rags, after being boiled, are brought to the *washing engine*, which performs a very important part in the manufacture of paper. This engine, which is represented in Fig. 381, is a large iron vessel, into which the rags are put for the purpose of cleansing and reducing them to what is called *half-stuff*. For this purpose the rags are made to revolve among water, a constant supply of which flows in at one end of the vessel, and an equal quantity is lifted out at the other by means of a revolving cylinder covered with wire cloth. This engine is of various sizes, generally about twelve feet long, from four to five feet in width, and two deep. An iron partition runs about eight feet along the centre, leaving a space of two feet open at each end. A few perforated plates are placed in the bottom to allow any sand or dirt to escape, and a grooved box in front of the roller to catch any buttons or hooks, or other hard substances, which may have escaped former processes. Across the centre of the

engine is a spindle, A, of wrought-iron, four or four and a half inches diameter, one end of which carries a pinion, B; the other end rests on a frame or lighter, C C, which can be raised or depressed by means of a screw, D. On this spindle is an iron cylinder or roll, E,

Fig. 381.



generally twenty-four inches in diameter by twenty-eight inches in length, and mounted with forty bars or knives at regular intervals, projecting about two inches, so as to make the extreme diameter twenty-eight inches. The roll makes from one hundred and twenty to one hundred and thirty revolutions per minute, and under it is fixed a plate composed of ten or twelve knives, five or six inches wide, and equal in length to the roll. This plate is fixed in a box or seat, F, in the bottom of the engine. Over the roll is a wooden cover, to prevent the rags and water from flying off by the rapid revolution of the roll; and across this cover is placed a screen of fine wire-cloth, against which the rags and water are dashed by the motion of the roll. In the figure, the cover and screen are removed, to exhibit the internal apparatus. The water, passing through the screen, is carried off by pipes, while the wire-cloth prevents the rags from escaping. Formerly these screens, one before and one behind the roll, were the only means of carrying off the dirty water.

In the year 1837, CHARLES COWAN of Valleyfield Mills invented and patented a revolving washing cylinder, which greatly improved the washing power. This cylinder, which consists of fine wire-cloth, contains a series of circular buckets, starting from a common centre on a spindle, and projecting to the circumference of the cylinder. The latter is twenty-four inches wide by thirty inches diameter, and being immersed in the engine to the depth of six inches, revolves among the rags, while the buckets successively lift the water and pour it out at the centre into a spout. When the engine is empty the rags are brought to it in a box. The roll is lifted entirely free of the plate by means of the lighter screw. A stream of water is then turned into the engine; and as soon as it rises to the level of the roll the workman begins to introduce the rags, spreading them on the surface of the water. About a hundred and fifty pounds are put in at one time. The rotatory motion of the roll draws the rags between the roll and plate, and dashes them from one side to the other, until, being carried round in the spaces between the knives, they are thrown out on the other side. By this action the level of the water is depressed in front of the roll, and on passing through to the other side, it endeavors to regain its level, whereby it flows round the end of the mid-

feather, back to the front of the roll. A continuous circulation of the rags is thus maintained, and the flow of water into the engine is regulated by the quantity lifted out, which is greatest at the commencement; for as the rags are rubbed down into fibre less water is lifted by the washing cylinder. Papermakers calculate on the washing engine using from forty to sixty gallons of water per minute. When the rags have been fifteen to twenty minutes in the engine the roll is gradually lowered, until nearly its whole weight rests on the plate.

The motion of the roll over the plate draws the rags into a fibrous substance called, as already stated, *half-stuff*. Experience and care are required in this operation. If it is performed too quickly, or if the rags are cut too short, the paper will be weak, and a great loss of fibre in future operations will be the consequence. If, on the other hand, the rags are not drawn into fibre they do not bleach equally. It requires not less than two hours to reduce the rags to half-stuff; by this time they should be cleansed, and in a fit condition for being bleached.

In the process of washing the rags a considerable quantity of fibre passes away with the water. To save this fibre, which can be used for inferior papers, Messrs. JAMES PAISLEY and GEORGE BERTRAM have invented and patented a conical cylinder covered with fine wire-cloth. The water, as it passes from the engine, enters the small end of the cylinder, and as it flows down to the wide end, percolates the wire-cloth, leaving whatever fibre it contained. This cylinder can also be applied to recover the fibre which the waste water from the machine contains.

Several other improvements have been made at different times upon the washing engine, professing to increase its washing power and save fibre; but none of them, so far as the Editor is aware, have proved of practical value.

Bleaching.—The quality which chiefly distinguishes the paper of the present day from that made thirty or forty years ago, is its pure white color, which can only be obtained by bleaching. When the art of decoloring with chlorine gas was introduced about the end of last century, manganese and chloride of sodium were mixed together in a close vessel, and sulphuric acid was poured upon them. The chlorine thus generated was conveyed in pipes to a close chamber, in which were placed the rags to be bleached. In the chamber they were exposed to the action of the gas for some hours, and by this means a good result was obtained; but it was a difficult operation, and injurious to the health of the workmen.

When chloroxide of calcium, or lime impregnated with chlorine, was introduced, the method first practised was to put the lime into an iron or lead box and mix it with water. The gas, having a stronger affinity for the water, combined with it, forming what is called bleaching liquor. When the rags had been well cleansed in the washing engine, and reduced to a coarse fibre, as already described, the flow of water through the engine was stopped, and a portion of the bleaching liquor was introduced among the *half-stuff*. The roller was then lifted off the plate, and the stuff was made to circulate in the engine about an hour, which effected a great

improvement in the color. The process of washing was then resumed, and continued until the gas was washed out, after which the stuff or pulp was emptied into the beating engine.

To this method there were several objections, one of which was that the whole of the gas that remained in the stuff when the washing was resumed was lost. About 1820 the present method of bleaching in stationary chests, and thereby saving the liquid which still retained a considerable quantity of gas, was generally adopted by manufacturers.

Present Method of Bleaching.—A quantity of chlor-oxide of calcium is put into a circular stone cistern filled with water. An upright shaft, which revolves on a bearing in the bottom of the cistern, and has arms projecting to within a few inches of the side, mixes the bleaching powder with the water. When the agitator is stopped, the lime settles to the bottom, leaving a clear liquid with a green tinge, which constitutes the *bleaching liquor*. The proportion of lime and water is generally one pound of lime to two gallons of water, and it is expected to stand 8° of Twaddell's hydrometer, but seldom stands more than 7°.

When the rags have been brought by the washing engine to a fit condition for being whitened, they are emptied into the bleaching engine, which is placed on a lower level to admit of the stuff being discharged into it by a pipe. The bleaching engine is similar in construction to the washing apparatus, but has no plate, as its only office is to mix the stuff with the bleaching liquor. It is made of stone to resist the action of the chlorine, and a part of the bottom is laid with perforated zinc plates, to admit of the stuff being drained. This is generally done by a pump, and the water is used over again for washing the next charge of stuff. When this half-spent lie has been introduced into the bleaching engine, there is added to it a portion of strong liquor, generally from eight to sixteen gallons to the hundredweight of rags. This quantity of bleaching solution contains as much gas as exists in four to eight pounds of lime. The stuff is then allowed to run from fifteen to twenty minutes, and is finally emptied into the bleaching-house, where it remains from eighteen to twenty-four hours.

The bleaching-house is a separate apartment, in which are generally placed two rows of stone boxes or chests, each of sufficient capacity to receive the contents of two engines of stuff. To allow sufficient time for bleaching, there ought to be as many chests or boxes as will contain the supply of stuff required for thirty hours.

Some papermakers allow the *half-stuff* and chlorine to remain from forty-five to fifty minutes in the bleaching-engine, under the impression that the color is thereby improved. It cannot be denied that the color improves very rapidly under the process; but when it is continued more than twenty minutes, the action of the roll on the stuff causes the chlorine to evaporate, which is easily perceived by the smell, and greatly reduces the bleaching powers of the liquor.

About four years ago Mr. DUNCAN of Denny invented a different method of bleaching, which he protected by a patent. The principle of his improvement

consists in the application of heat to the pulp while in the bleaching engine. According to his published statement, its advantages over the old method are, that it is more economical, produces a better pulp, and is more quickly effected; the whole process not occupying an hour. But whatever be its merits, it does not appear that this mode has found much favor with paper manufacturers.

When the stuff is sufficiently bleached, the clear liquid is pumped into a cistern for further use—it being a property of the liquid that it not only extracts but destroys the color, and, therefore, does not become impure by bleaching. On the other hand, the stuff or pulp is put into a strong iron box, and submitted to the action of a hydraulic press, which prepares it for the beating engine.

BEATING ENGINE.—The *beating engine* is of nearly the same construction as the washer, and is used for grinding the *half-stuff* into a fine pulp fit to be made into paper. The roller contains fifty-four, and the plate from seventeen to twenty-four knives. A stream of water is turned into the engine; the *half-stuff* is then introduced, and mixing with the water, is drawn between the roll and plate, producing a continuous circulation, as in the washing engine. Before the roll is lowered to the plate, the *half-stuff* is allowed to run for thirty or forty-five minutes, to wash out the chlorine, which, if suffered to remain, is found to be injurious to the paper.

Within the last few years hyposulphite of soda has been used to neutralize the chlorine. A small quantity of this salt is dissolved in water; and this, being put into the engine, instantly seizes the chlorine, and by combination neutralizes it, forming sulphate of soda, a substance harmless to paper. The washing is then resumed, and continued for a few minutes, to remove the new compounds formed. It may here be remarked that since hyposulphite of soda, or, as it is technically termed, *antichlor*, came into use, the time of washing in the beating engine has been reduced to twenty minutes, thereby effecting a saving of twenty-five minutes, which can be applied to the grinding of the pulp, and, at the same time, no traces of chlorine remain in the paper.

If the pulp is required for printing papers, a solution of soda and rosin is now put into the engine; and, after being well mixed, a few pounds of alum are added, which, combining with the soda, allows the rosin to adhere to the pulp; this is called *engine-sizing*, and is done with the view of preparing the paper to bear ink when printed. Any coloring matter which may be required is next introduced; the roll is then gradually lowered on to the plate, and the process of *grinding*, or reducing to fine fibre or pulp, commences.

The pulp is made long or short according to the quality of the paper. Newspapers, which require strength, are made of long pulp. Writing paper, or paper of a fine texture, is made of shorter pulp. In fact, the quality of the paper depends very much on the manner in which the pulp is prepared in this engine. If the roll is lowered too rapidly the fibre is cut, and produces a tender paper; and, owing to the porous nature of this paper, the sizing, whether for printing

or writing, will be weak. The stuff should be what is called *mellowed* in the engine, and this is effected by a judicious working of the roller—not lowering it suddenly or much at one time, on to the plate; but equally and gradually, until the pulp is ground as fine as is required. This is generally attained in three and a half to four hours; after which the engine is emptied into the stuff chest or reservoir, which is a large cistern capable of containing five thousand or seven thousand gallons of this prepared pulp.

To give an idea of the number of cuts or bruises to which the rags are subjected, it may be stated that the roll containing fifty-four knives revolves a hundred and fifty times per minute over the plate containing twenty knives, thereby making no less than a hundred and sixty-two thousand cuts every minute. This rotary engine was invented by the Dutch about the middle of the last century, and is known by German papermakers as the *Hollander*. Although not free from some defects, it is a great improvement on the old mortar engine. And while great advances have been made in papermaking during the last thirty years, the chief improvement on this engine has been the revolving washing cylinder, already described. The principal defect of the engine arises from this, that while a certain quantity of rags is put into it for the purpose of being ground to fibre or pulp, these rags are not of the same tenacity, and being kept under the action of the grinding process for three or four hours, the weaker rags are reduced to a finer pulp than those of a stronger texture. Also, one engine may be emptied into the reservoir which contains pulp of a longer or shorter fibre than the previous one. In fact, there is no security against this evil but the care and skill of the workman; and, notwithstanding every precaution, it sometimes materially affects the quality of the paper.

To overcome this difficulty, JOSEPH KINGSLAND of New Jersey has secured a patent for a centrifugal pulp engine, which is said to be working satisfactorily in his mill in New Jersey, producing a uniform pulp. This machine has been adopted by EASTON and AMOS of London, by whom further improvements have been made upon it, and who, having also experimented with it at Phoenix paper-mill, Dartford, state, that having now fairly tried it, they are convinced it is a valuable machine, one capable of producing better pulp with less power than any other engine hitherto produced; and that, consequently, its adoption would secure to papermakers very considerable advantages. Hence they are persuaded that it must come into extensive use.

This invention consists in placing a revolving grinder between two stationary grinders; the fibre to be ground or reduced to pulp being caused to pass in a current through the spaces between one of the stationary grinders and one side of the revolving grinder, thence round the periphery of the revolving grinder and the other stationary grinder, to the orifice of discharge. In its actual operation a stream of pulp well mixed with water flows by a feed pipe under, say, four feet pressure into the engine, between the revolving grinding surface, which makes two hundred revolutions per minute against the stationary grinder, and the distance

between the two surfaces can be regulated by a set of screws, thereby producing coarser or finer fibre as required. The moment the fibre is ground it passes into the reservoir. A constant stream is thus flowing through the engine at the rate of a hundred and fifty pounds of paper per hour. The Editor has no doubt but that in a few years this engine will supersede the present beating engine, and will greatly simplify the mechanical operations of the papermaker.

The thorough neutralization of the chlorine is an important matter. When machines began to be generally introduced, the engines in many mills were not adapted for the increased quantity of work a machine could perform, as compared with vats. Too little time was therefore given to the preparation of the pulp, and the chlorine was not sufficiently washed out; and as chlorine, if left in pulp, continues to act on the paper, causing a premature decay, complaints were consequently very frequent, and the decay was ascribed to excessive bleaching and the use of mineral substances. This, although a natural opinion, was not the less a mistake. Excessive bleaching will make paper weak or tender, but if the chlorine has been neutralized it will not otherwise injure it. Mineral substances were at one time pretty freely used, and in some mills this may still be the case. A small quantity is not injurious to paper, and is sometimes used to close the pores, thereby improving the surface. But experience has taught paper manufacturers that the injury these substances do to felts and wires is poorly compensated by any little addition to weight which is obtained from them; and since antichlor came into use, by which the chlorine is easily neutralized, the complaints above-mentioned have been seldom heard.

PAPERMAKING BY HAND.—Having described the method of preparing rags to make paper, the Editor will briefly advert to the old way of manufacturing it.

In papermaking, as first conducted in Europe, the rags were neither boiled nor bleached, but were only cut and assorted; and to facilitate the cleaning and reducing to pulp, they were steeped in water, then laid in heaps, and allowed to ferment and putrefy. This loosened the texture, and prepared them for being cleansed and reduced to pulp. The process of reducing the rags to pulp was performed by stamps or mallets working in a strong wooden box or mortar. A stream of pure water was allowed to flow through the box, thereby carrying off all impurities. This process was continued until the rags were clean, and was necessarily very slow and tedious. When the rags were considered fit to make paper, they were emptied into a chest, from which the pulp was lifted into a vat. This vat was simply a cistern about three and a half feet high, six feet square at top, and tapering nearly to a point at bottom; near which a small agitator revolved, keeping the pulp of an equal consistency throughout.

The sheet of paper was made by a mould, composed of a frame covered with fine wire-cloth, having a movable edge called a *deckel*. This mould the workman dipped into the vat, lifting a portion of the pulp on its surface. The water flowed through the wire-cloth, and left the fibre on the top. The workman then removed the deckel, and passed the mould to another,

who turned it over, and pressed it on a felt, to which the sheet adhered; the mould was then returned to form a new sheet.

About one hundred and thirty sheets were now laid in alternate layers of felts and sheets, and the whole submitted to powerful pressure, which forced out a large quantity of water, and made the paper sufficiently firm to bear handling. The sheets were then taken out of the felts, and being laid together, were subjected to another pressure, after which they were parted or turned over, to prevent their adhering to each other. The paper was then taken to a drying-house, and hung up on lines to dry; from four to eight sheets were hung together. In favorable weather the paper would dry in from three to five days, and in damp weather the drying-house was heated by steam. After being thus exsiccated, it was dipped into size or glue, for the purpose of closing the pores, and enabling it to bear writing upon. When sized, it was gently pressed, and each sheet parted from another, and hung up a second time to dry in the loft or drying-house.

The system of making paper by hand was very slow; it occupied at least three weeks from the preparation of the rags to the finishing of the paper, and often subjected the manufacturers to considerable loss. To work one vat, which would make on an average one hundred and fifty pounds of paper per day, or what can now be made by a machine in one hour, required eight men, and eight or ten women.

There are still a few vats working in the country, generally in the manufacture of paper for which great strength is required; and at Maidstone, in Kent, there are still two mills or factories engaged in hand-making. These were established about one hundred years ago by Mr. JAMES WHATMAN, and great improvements were introduced in them. The paper of one of these mills is still marked—J. WHATMAN, Turkey mill; that of the other is marked simply, —J. WHATMAN. The manufacture of these mills has not yet been equalled, whether by hand or machine made paper.

HISTORY OF THE PAPER MACHINE.—The paper machine, by which so great a development of the paper trade was effected, had its origin in France. LOUIS ROBERT, a clerk in the employment of DIDOT, was the first who appears to have conceived the idea of making a continuous web of paper on an endless wire-cloth, to which a rotary motion was communicated, thereby producing a web or sheet of indefinite length.

However simple this idea may appear to those who are acquainted with the present system of papermaking, it was nevertheless a most extraordinary conception at the time, and marks out the inventor as one of those original thinkers whose ideas, being worked out by men acquainted with details, have done so much to extend manufactures and benefit mankind.

About the year 1798, ROBERT constructed a small model of a machine, by which he could make a narrow continuous strip of paper. M. DIDOT, his employer, became interested in his labors, and with this gentleman's assistance, a machine was constructed by which paper twenty-four inches wide could be produced. But though this rude apparatus might be sufficient to

demonstrate the possibility of applying the rotary motion to papermaking, yet either from the impatience of its inventors, or more probably from its defective construction, it does not appear to have been used for practical purposes, but merely as a subject of experiment. At the same time its merits did not pass unnoticed. Although not immediately put into practical use in France, yet the French government, with just discrimination, presented to ROBERT the sum of eight thousand francs, as a reward for his invention, and the right to it was purchased by M. DIDOT for the sum of twenty-five thousand francs, while that gentleman's brother-in-law, M. GAMBLE, secured a patent for it in England, and also obtained an introduction to the Messrs. FOURDRINIER, who at that time were extensive stationers and papermakers. Messrs. FOURDRINIER entered with great zeal into the project, and under the superintendence of BRYAN DONKIN, they in three years succeeded in constructing a machine which made a continuous web of paper; but, after three years more of intense labor, and an expenditure of sixty thousand pounds sterling, the patentees found that their machine still required extensive alterations and improvements. They therefore applied to Parliament for an extension of their patent for fourteen years.

The bill passed through the House of Commons, but as stated by the late Dr. URE, by an unworthy artifice of Lord LAUDERDALE's, it was limited to seven years, with an understanding that the patent would be extended other seven years if at the end of the first period they could show that they had not been remunerated for their outlay. However, they were prevented from reaping the benefit of this arrangement by a standing order of the House of Lords, subsequently placed on their journal, which allowed an extension of a patent only to the original inventors. Messrs. FOURDRINIER being thus prevented from reaping any advantage, or deriving any remuneration in return for the capital expended, became involved in difficulties, which led to their bankruptcy.

To show the advantage of this invention, Mr. FOURDRINIER in 1806 published a statement, showing the cost of working a machine capable of doing seven vats' work, compared with the cost of working seven vats. He shows the cost of the latter to be two thousand six hundred and four pounds sterling per annum, which would now be considerably increased by the higher wages paid to workmen; the cost of the machine doing equivalent work he calculated at seven hundred and thirty-four pounds sterling per annum, and this, on the contrary, would now be diminished, owing to the improvements which have been made, and the greater quantity of paper produced in the same time. But taking his own figures, he thus demonstrated a saving, by his invention, of one thousand eight hundred and seventy pounds sterling upon seven vats in one year. The cost of making paper by vat he showed to be sixteen shillings per hundredweight: by machine only three shillings and ninepence; and in 1807 he offered to make such machines at from seven hundred and fifteen to one thousand and forty pounds sterling, according to their width. He also points out as another advantage of the machine, that of relieving the

manufacturer of all difficulties arising from combinations among workmen.

It is a lamentable fact, remarks the late Dr. URE, that the attention required to mature this valuable invention, and the large capital which it absorbed, led ultimately to the bankruptcy and ruin of this opulent and public-spirited company; after which disaster no patent dues were collected, though twelve suits in Chancery were instituted; these being mostly unsuccessful on account of some technical objections made to their well-specified patent by that unscientific judge, Lord TENTERDEN. The piratical tricks practised by many considerable papermakers against the patentees, are humiliating to human nature in a civilized and *soi-disant* Christian community. Many of them have owned, since the bankruptcy of the firm removed all fear of prosecution, that they owed the company from two thousand to three thousand pounds each for patent dues!

PRESENT PAPER MACHINE.—When the pulp is properly prepared, it is emptied into the stuff-chest—in which an agitator revolves for the purpose of keeping the pulp and water at an equal consistency—and is thence drawn as required to suit the machine. Before describing the latter apparatus, it may be necessary to state that an important desideratum in paper is *uniform thickness*, and this can only be obtained by a uniform supply of pulp and a regular speed of machine. Formerly, this uniformity depended entirely on the care and attention of the workman; but in drawing the pulp to supply the machine by a pipe from the chest, the pressure was always varying and making irregular paper, and the workman could scarcely regulate his valve or supply-cock to the exactness required. When an engine of pulp was emptied into the chest or reservoir, the pressure on the valve was increased, and the workman, by his own judgment, had to lessen the orifice of discharge; but, however attentive he might be, he could not regulate the valve with perfect certainty, or in precisely the same ratio as the increase or decrease of pressure in the chest.

To overcome this irregularity in thickness, papermakers tried various methods, but the two modes in general use are by a pump and a pulp meter.

Pumps and Pulp Meters.—When pulp is delivered to a machine by a pump, the latter is applied to pump the pulp from the large chest into a small one placed above it, in which is an overflow, so that if the supply to the machine be rapidly stopped, the pulp will immediately flow back into the large chest. A regular quantity of pulp is thus kept in the small one, to which the supply-pipe is attached, and a uniform pressure is in this way obtained.

The other mode by *pulp meter* was introduced by Messrs. COWAN from OECHELHAEUSER, the foreign inventor, and consists in making the pulp, which is kept at an equal density, flow into a cistern, in which a box constantly dips, lifting an exact quantity of pulp. The capacity of this box can be increased or diminished, to correspond to the different thicknesses of paper required. The writer has seen this pulp meter work for twelve hours, and the workman in attendance never require to touch it, while the paper produced would not vary in weight one half pound per ream.

Lifter Wheel and Sand Trap.—From the pump or pulp meter the pulp flows into the *lifter wheel*, and is further diluted with water. This is a wheel composed of buckets, into which the *save-all* water flows, and is by them lifted to its former level for the purpose of being used again. The pulp and water are both lifted and discharged on to a *sand trap*, which is a long flat box from twenty to forty feet in length, and only four or five inches deep. The pulp flows over this surface, and allows sand to settle on the bottom. From this the pulp flows into the strainer.

The Strainer is a brass frame, of which the bottom is composed of brass plates finely perforated, and through which the pulp has to pass longitudinally, thereby keeping back all knots and impurities. A quick, vertical motion is given to it; the pulp flows in on the top, and percolates through the bottom by suction; it then passes into the vat. A great variety of these strainers are in use; but the best which the writer knows of is made by EASTON and AMOS of London. Their strainer is a fixture, and below it is a piston, which is made to work vertically against the bottom of the strainer, without touching it. A rapid motion is given to this piston, and the suction thereby created carries the pulp through. This patent strainer is a great improvement on the old one. While the latter has to be cleaned every twelve or twenty-four hours, this will work for sixty or seventy hours without cleaning.

The Wire.—From the strainer the pulp flows by two pipes into the vat, which is a large box for containing a supply of pulp, and from this it passes to the *wire*. The latter, which constitutes a most important part of the mechanism, is generally an endless web of fine wire-cloth, of three thousand six hundred to five thousand meshes in each square inch. It is about thirty feet in length, and is made to revolve on two rollers—always presenting a level surface of twelve or fifteen feet to receive the pulp. To admit this liquid to the wire, a slit or opening runs along the front of the vat, by which the depth of pulp is regulated. The latter flows through this opening upon an apron or delivery board, and from thence to the wire, beneath which is placed a box called a *save-all*. The lateral motion of the wire shakes the fibre of the pulp together, while the water passes through the meshes of the wire-cloth into the *save-all*, and thence into the lifter wheel, to be used over again.

The fibre being left on the surface of the wire, gradually becomes firmer and more compact; and is regulated in width by *deckel* straps or bands, which form ledges at or near the sides of the web, and prevent its flowing off the wire. These bands or deckels are made of a number of layers of cotton, gummed and sewed together, being about one inch in width, and half an inch thick; sometimes they are made entirely of vulcanized india rubber. They travel along with the wire, one on each side, and by their flexibility keep the pulp to any required width. They are guided by a frame which stretches across the machine, resting on its framework; and the breadth of pulp is regulated by widening or narrowing the frame.

The Dandy Roll.—Travelling with the wire, the

pulp passes to the dandy roll, which is simply a cylinder, the two ends of which consist of brass hoops fixed on a shaft, and having wires extended between them; or it is sometimes formed of perforated copper, and is covered with fine wire-cloth. It is generally seven inches in diameter, and usually corresponds in length to the width of the wire upon which it rests. The journals of this roll turn in slits in two upright stands; one behind the machine frame and the other in front of it; but, as the roll actually rests with its whole weight on the wire, it revolves by the progressive motion of the latter, while the stands prevent it from participating in the lateral motion. This roll, by running on the surface of the pulp, presses out a great quantity of water, and renders the paper finer and closer in texture.

The dandy roll appears to have been invented by Mr. JOHN WILKS, an English mechanist, for the purpose of pressing out some of the superfluous water. This object was afterwards more effectually accomplished by the pump-box, but the dandy was still found to be a valuable invention for closing the pores of the paper. It is also by this part of the mechanism that the water-mark and the lined appearance which laid paper presents are impressed.

Suction Boxes.—Beneath the dandy roll, and across the machine, two suction or pump boxes are placed, having their upper sides open. As the wire travels over these boxes, the action of the pumps with which they are connected draws the wire upon them with a pressure sufficient to make them air-tight, thereby extracting a large portion of the water which the pulp at this point still retains, and giving to it such a degree of consistency as fits it to bear without injury the pressure of the couch rolls. Before this apparatus was introduced, the pulp often came too wet to the couch rolls, causing the paper to be water-galled.

The Couch Rolls.—The web of paper being regulated in width by the deckels, rendered closer in texture by passing under the dandy roll, and made drier and more compact by passing over the suction boxes, now arrives at the couch rolls. These are two large rollers covered with felt; the under one revolves inside the wire, and gives the motion to it; the upper rests on the lower, and thus both wire and web of paper pass through between them, receiving a gentle pressure, which renders the paper still more compact.

At this point the paper leaves the wire, and is received on a soft woollen blanket, or endless web of felt, which revolves continuously on rollers, and is about twenty feet in length. This endless web carries the paper between two heavy iron rollers, called press rolls, which still expel a large quantity of water. The paper can now bear its own weight, and may be handled gently without injury.

Steam Drying.—For many years after the introduction of the paper machine, the paper, after passing through the press rolls, was wound on reels, cut into sheets by hand, and then hung up in the loft to dry. But in 1821 a very useful improvement was added to the machine by T. B. CROMPTON, who invented and patented a new mode of drying by heated cylinders, and a cloth or felt. According to Mr. HERRING, the

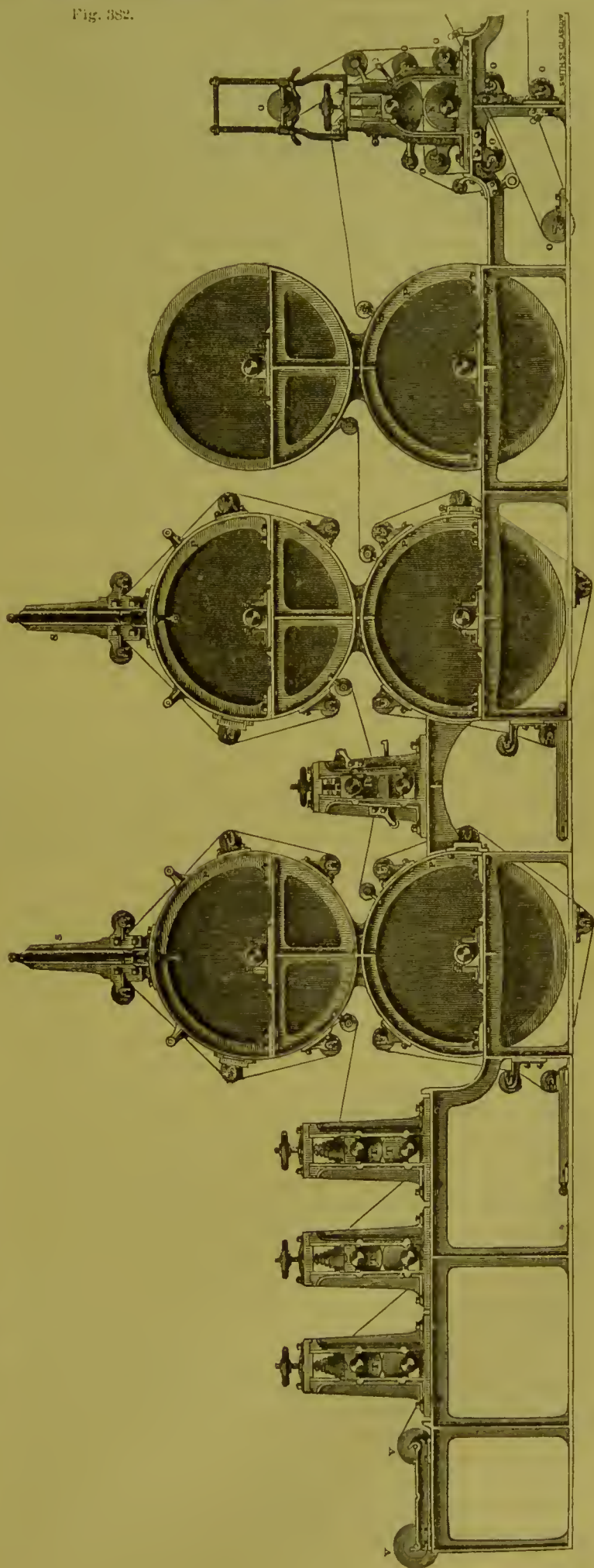
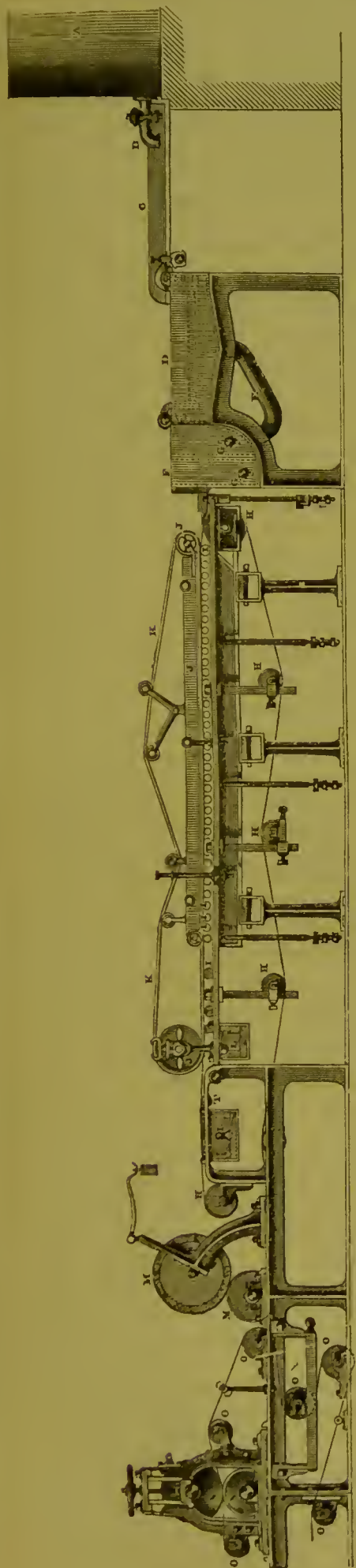
first experiment for drying paper by means of heated cylinders was made at GELLIBRAND'S calico-printing factory, near Stepney, a reel of paper in a moist state having been conveyed thither from Dartford in a post-chaise. The experiment, which was made in the presence of the patentees of the paper machine and Mr. DONKIN the engineer, proved highly satisfactory; and the adoption of copper cylinders heated by steam was thenceforth considered indispensable. But copper cylinders were soon superseded by cast-iron ones. The former, being thin, did not retain the heat any length of time, and were rapidly heated or cooled by the least variation of pressure on the steam. The cast-iron drying cylinders at present used are made thicker, and although not so quickly heated, retain their heat longer; while any irregularity in the pressure or temperature of the steam does not so easily affect them. The number of cylinders in a machine varies from three to fourteen; they may be placed in a great many different ways, and are used of different sizes. But the best way to arrange them, is to set them in pairs, one over the other, leaving a few inches between the two surfaces.

The paper, after passing through the press rolls, and thereby parting with a quantity of water, is much firmer; but from the circumstance that the pressure on one side is exerted against the felt, it is rougher on that side than on the other; and to equalize the sides a second pair of press rolls and a short felt have been introduced. The paper passes from the first pair of rolls, presenting its rough surface to the smooth roll. It then passes on to the first drying cylinder, which should only be slightly heated; the second is heated a little more, and so on, each of the series of cylinders successively increasing in heat. By this means the paper is dried gradually, and is found to be much stronger when dried in this way than when passed over one or two very hot cylinders.

Papermakers have paid too little attention to the drying power of their machines; and in many places, while the speed of the machine has been greatly increased, the number of drying cylinders has remained the same; consequently, a great degree of heat has to be kept up, while the paper, nevertheless, is not so well dried; and in making printing paper, or paper sized in the engine, this high temperature and its quick application cause a great quantity of size to evaporate, leaving the paper imperfectly sized. Enterprising and scientific papermakers have now remedied this defect by increasing the number of their cylinders. Over a few of the cylinders is a felt web, which revolves with the cylinder, and the paper runs between cylinder and felt. The object of the felt is to dry the paper equally, and keep it from *cockling*.

In well-arranged mills, the cylinders are differently adjusted on machines for making writing and those for making printing papers. On a writing paper machine, the paper is only passed over a number of cylinders to dry it, then wound on reels. On machines for making printing paper, the paper passes over three or four cylinders, then between a pair of smooth, well-polished metal rolls, to give it a surface, and which is best done when the paper is a little moist; from these,

Fig. 382.



called *nipping rolls*, the paper passes over three or four additional cylinders.

Calendering.—The paper is now thoroughly dry, and from the last drying cylinder it passes through between one or two sets of calender rolls, to bring up the surface required. These calender rolls are often five in number—one large roll, with four small ones placed above it. The paper passing in at the top circulates to the bottom, and thence proceeds to the reel, on which it is wound. These rolls are very difficult to keep in order, and are giving place to another arrangement, which consists of two or three pairs of rolls, with springs on the top of the bearings of the uppermost roll. The rolls are placed in sets; two rolls in a set, and three sets on a machine, thereby bringing up a fine surface.

Having thus described the several parts of the paper machine, and followed the course of the paper from its first appearance in the shape of unsightly rags until it is wound on the reel, it will be necessary to add a connected and complete view of the entire mechanism, to render it thoroughly intelligible to the reader. With this view, the Editor gives in Fig. 382 an engraving of one of the most improved paper machines, recently designed and erected by Mr. GEORGE BERTRAM of Edinburgh, who is known throughout Europe for the durability and excellence of his paper machinery. Machines from his establishment are working in Sweden and Russia, as well as in all parts of Great Britain. In this figure, A denotes the pulp chest; B, valve for regulating the supply of pulp; C, spout for conveying pulp to strainer; D, strainer; E, pipe for conveying pulp from strainer to vat; F, vat; G G, small agitators for keeping the pulp of equal thickness; H H H, rolls for wire revolving on; I I I, small tube rolls for supporting wire; J J J, deckel frame with pulleys for regulating width of paper; K, deckel strap; L L, pump boxes between which the dandy roll is placed; M M, couch rolls; N N, first and second press rolls; O, rolls for felt revolving on; P, drying cylinders; R, nipping rolls; S, guide frame for dry felt; T, calender rolls for improving surface; V, reel filling with paper, and reel full.

Laid Paper and Water-mark.—When the machine was invented, only wove paper could be made by it, and it was then supposed that it would never be possible to make laid paper by it, or introduce a water-mark; but the invention of the dandy roll and pump box have removed this supposed insurmountable difficulty. It has been already stated, that when the wire passes over the pump box a large quantity of water is immediately extracted from the pulp. This gives it such a degree of consistency that any impression made on it at this point remains, owing to its passing instantly from a partially fluid state to one of greater consistency.

A dandy designed to make laid paper is covered with fine wire, laid longitudinally, leaving very small spaces between the wires. When a water-mark is required, whether a name or device, the figure or letters are made of fine wire and sewed on the surface of the dandy roll.

CUTTING MACHINE.—Previous to the introduction of cutting machines, the paper was uniformly wound on a reel, the diameter of which could be diminished

or enlarged, according to the size of sheet required. When the reel was filled, an empty one was put on, and the paper was cut off the full reel by the hand. This method of cutting occasioned a great deal of waste; many attempts were therefore made to produce a machine which would cut the paper into sheets as it issued from the machine, or as it was wound off a reel; but most of the plans, after repeated trials had been made and considerable cost incurred, were laid aside as impracticable. Mr. J. B. CROMPTON of England appears to have been the first who produced a really useful cutting machine. About 1821 he secured a patent for cutting paper into suitable lengths by a pair of shears, as it issued from the machine; and in 1828 he again obtained a patent for cutting paper lengthwise by revolving circular blades fixed on a roller parallel to a cylinder. Finally, in 1849, AMOS and CLARK patented a cutter which obviated the difficulty that arose from the constantly increasing velocity of machines, causing the sheets to be cut into irregular lengths; and this cutter is the best yet in use.

The first operation of this cutter is to cut the paper lengthwise into such widths as may be required. To effect this object, there are placed across the machine two shafts, armed with circular blades, which may be moved along the shafts to adjust them to any required width. These knives revolve at a much greater speed than the paper, which, as it issues from the making machine, or is wound off the reel, passes between the two shafts, and is cut by the knives very exactly. It may be stated that the knife on the upper shaft is larger in diameter than that on the lower, and as they revolve in contact, the action produced is similar to that of a pair of scissors.

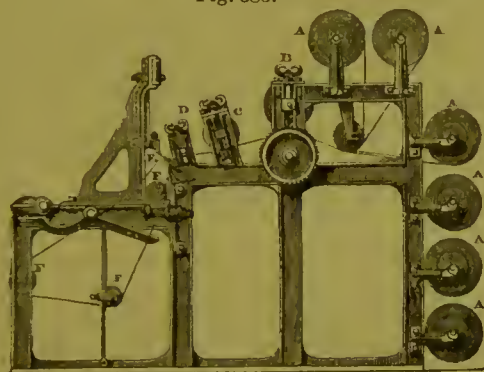
The web being thus cut lengthwise, proceeds over a large drum for the purpose of being cut across into the lengths required for the sheets. From the velocity with which the paper travels, this is a difficult operation, and requires the paper to be momentarily arrested in its course, at regular intervals, to admit of the sheet being cut square. With this view, the drum is so contrived as to have an alternating motion: at one time bringing the paper forward the required length, and then returning. This effect is produced by a crank arm, which can be adjusted at pleasure to regulate the length of the sheet. In front of this drum, at the point where the paper leaves it, is placed a solid board or wooden block, over which is suspended a movable board or presser. The paper passes between these, and when the drum has brought forward the required length of sheet, the presser, by a particular movement, is made to descend against the block, and holds the paper fast, while at the same instant a combined motion of rolls and levers brings a movable knife against a fixed knife, and the paper is cut in the same manner as by a pair of shears. The sheets immediately on being cut are caught by boys, and laid straight in handbills. The drum, after bringing forward the required length, immediately retrogrades, while the pressers prevent the paper from being pulled back along with it. Three rolls covered with felt are placed on the top of the drum to assist in bringing forward the paper, and the moment it is held fast in the

pressers these rolls are raised by a lever and connecting rods, so that the paper is left loose on the drum, which by this arrangement can turn back without dragging the paper. The latter is continuously passing between the knives, and while the drum is making its backward motion, a *dancing roll* takes up the slack of the paper.

This cutter is invaluable in cutting laid paper on which is a water-mark. As this water-mark requires to be in the centre, from which it sometimes deviates, a portion of the machinery can at any time be stopped by hand, and a small part of the sheet cut off, thereby bringing the water-mark again to its proper place.

In addition to the cutter just described, and which is certainly the best in use for cutting paper with water-mark, there is another which also has its advantages, and of which the annexed engraving—Fig. 383—has been kindly furnished by Mr. GEORGE BERTRAM. This machine is generally used for cutting wove paper, printing paper, and newspapers, and cuts six webs at once. Six reels turn on bearings in a frame, and the web from each, passing round a smaller roller, is received

Fig. 383.



on a small drum. All the six webs, passing round this drum, are collected on a pair of small rollers, called *gathering rolls*, and by these they are simultaneously subjected to the action of the circular knives, which cut the paper lengthwise, forming the required width of sheet. By a wheel and lever, which regulate the motion, the requisite length of paper is then brought under a movable upright knife, which immediately descends on a fixed or bed knife, and severs the sheets from the webs. The sheets are then carried forward on a revolving apron to boys, who pile them carefully in handfuls; after which the paper is taken to be overlooked and finished. This description will be easily understood by the figure, in which A represents the six reels of paper on cutter frame; B, gathering rolls; C, circular knives for cutting paper longitudinally; D, feeding rolls; E, movable and fixed knives for cutting paper from web, usually called *cross-cutting knife*; F, endless apron for carrying paper to boys. This cutter has the advantage of being capable of performing about double the work of the one previously described, and is therefore used in mills where the water-mark is not put on paper.

SIZING.—Inferior sorts of writing paper, and all continental writing paper, are sized in the pulp, by the same method as printing paper; but to produce a good writing paper, it is necessary to size it with animal size after it is made.

Size is generally made at the mill from the parings of skins, called *scrolls*. Formerly the scrolls were boiled until the gelatin they contain was extracted, but the size had often a turbid appearance, and injured the color of the paper. About 1840, the Messrs. PIRIE of Stoneywood, Aberdeen, obtained a patent for an improved method of making size. Their process consists in steeping the scrolls in stagnant water until putrefaction has commenced; the scrolls are then beaten with a mallet, well cleansed, and steeped in water strongly impregnated with sulphurous acid, which acid has the property of both arresting putrefaction and bleaching the scrolls. By this process the gelatin is much more easily extracted, and the scrolls do not require to be boiled. They are put into a large wooden vessel or tub, which is set inside a cast-iron one, and between the sides of these vessels there is a space of about one inch all round. This space is filled with water, into which steam is admitted, and by the heat thus communicated the gelatin is extracted; but unless the heat is kept considerably below the boiling point the size will not be pure. When drawn off, a quantity of alum is dissolved among it for the purpose of preserving it. By this method a fine pure size is obtained, which does not injure the color of the paper; but the process is complicated, and the gelatin contained in the scrolls is liable to be injured by allowing putrefaction to proceed too far when the scrolls are being steeped. It has now, however, been found that a part of this process may be omitted, and that copper instead of wooden vessels may be used without detriment to the size.

The sizing of paper by hand-dipping was a tedious process, and occasioned a great deal of waste. Many attempts were therefore made to size it in the web, which for a considerable time were unsuccessful. About 1840 several mills succeeded in attaining this object, but with some little diversity in their methods. The mode adopted by Messrs. ALEXANDER COWAN and SONS at their mills, is to pass the paper over two rolls, about a foot in diameter, half immersed in size. Behind these rolls is a frame fitted with small rolls set at an angle. Paper, when undergoing the process of wetting, expands considerably, and these rolls have the effect of keeping the web of paper stretched to its full width, thereby preventing it from getting into creases as it passes to the press rolls, where the superfluous size is pressed out. Another and simpler method is to pass it under a drum about two feet diameter, half immersed in size, and then forward to the press rolls.

The sizing of paper is an important but difficult process. If the paper is very porous, it is also generally weak, and then the sizing occasions a good deal of waste. If again the paper has been blued with ultramarine, a strong and offensive smell is often communicated to it. The best remedy for this is to use a size which has not been long kept, to allow the paper to lie some time after being made, and after sizing to dry as quickly and as perfectly as possible. If it still retains any offensive smell, this may be partially removed by hanging it up in a place where it can be exposed to a very dry atmosphere.

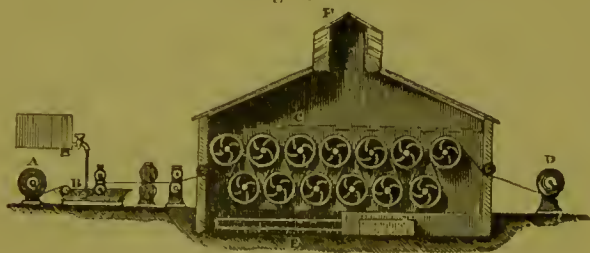
DRYING.—Manufacturers having succeeded in sizing in the web, the next desideratum was also to dry it in

the same form, which, after many unsuccessful attempts, was accomplished.

The drying machine is a large frame of cast-iron, about ninety feet long and nine wide. In this frame are laid two and sometimes three tiers of skeleton drums or cylinders, three feet in diameter. A shaft passes through the centre of each drum, and to the shaft inside of the drum are fixed two arms called fans. The shaft is driven by a separate arrangement of the machinery, and is independent of the motion of the drum. The paper travels over the drum at the rate of from forty to sixty feet per minute, while the shaft is making about one hundred and eighty revolutions per minute, thereby producing a considerable agitation in the atmosphere around the dryer. Six sets of narrow bands, about one inch wide, pass over the drums from end to end of the dryer, for the purpose of conveying the paper from one drum to another. In some mills the paper passes at once from the sizer over the dryer; but generally it is wound on a reel at the sizer, and allowed to stand a few hours until the paper has cooled a little, and absorbed the size which is lying on the surface when it comes from the sizer. To convey the paper over the drying drums the end of the web is placed between the bands—three of the sets being above the paper and three below. It generally takes about fifteen minutes to travel over the dryer, and by the time it has reached the opposite end it should be quite dry and ready for the cutter.

Fig. 384 is a sectional view of the sizing and drying apparatus, where A represents the reel of paper to be

Fig. 384.



sized; B, the size cisterns and press rolls; C, drying drums with fans inside; D, dried reel of paper; E, heating apparatus; F, ventilator.

The drying machine is of great advantage to the paper manufacturer in regard to economy of time, but not otherwise. Paper when drying has a natural tendency to contract, and this is counteracted by the tension at which it must be kept when drying on the machine. Paper so dried is, therefore, not so tough as it would have been by the old method of hanging it on ropes. To meet this defect a much stronger size has to be used.

FINISHING.—The finishing, or smoothing the surface of printing paper, is now performed at the machine. After it is cut it does not require much labor. The first process is overhauling or overlooking. This is done by women, who turn over and examine every sheet, and lay aside all that are imperfect, or which have any small defect; these are called *retree*. Sheets seriously damaged are called *broken*, and when sold bring about half the price of sound sheets. The paper

is then counted into *quires*, each quire consisting of twenty-four sheets; and twenty quires, or four hundred and eighty sheets, constitute a *ream* of printing, wrapping, and colored paper. The reams are then subjected to heavy pressure before being put into covers. An excise label is pasted on the cover of every ream, and in this form it is set aside until wanted for the market.

Before being sent from the mill the excise-officer weighs the paper and writes the weight on it. He also requires the manufacturer to write or print the weight on each ream, and to put a progressive number on each. He further compares the weight on the ream with the gross weight, and if it exceeds or falls below the allowed per-centage, the paper is liable to be confiscated. Formerly the law required paper to stand twenty-four hours after being charged with duty; but this is now modified, and by complying with certain regulations paper may now be sent off a few hours after being charged with duty.

In finishing writing paper, a large amount of both labor and machinery is required. After it comes from the cutter it is pressed in strong hydraulic presses, and then rolled or glazed. The operation of rolling and glazing consists in subjecting the paper to a heavy pressure between highly-polished sheets of copper or brass. This part of the work is chiefly performed by women, who take one sheet of copper and another of paper, alternately, until they have about forty of each, which is called a *handful*. This quantity is then passed between a pair of rollers about fourteen inches diameter, set in a strong iron frame, and driven by steam or water power, working under a pressure of upwards of twenty tons. When the handful has passed through the rollers, the machinery is so constructed that the motion can be reversed, and by this means the handful is made to pass forwards and backwards several times, according to the smoothness or gloss of surface required. Highly-finished paper called *glazed*, and sometimes known as *satin* paper, is produced by simply repeating or prolonging this operation until the desired finish is obtained. To the manufacturer it is a somewhat costly process; for besides the expense of labor, which is considerable, injury to some of the paper is unavoidable, and the smallest flaw or speck in the sheets is brought strongly out by the high finish. It is evident, therefore, that writing paper which has to be highly finished, requires great care both in the preparation of the pulp, and in the manufacture of the paper.

The smoothing or finishing of the surface was formerly accomplished by placing the sheets of paper between glazed pasteboards. The boards, intermixed at intervals with *heated* iron plates, were then put into a press and subjected to heavy pressure—a process which is well known by the name of *hot-pressing*. It was very beneficial to the paper, as it took out any superfluous moisture, and made it handle firmly.

After the surface is smoothed, writing paper goes through the same process as that intended for printing, so far as regards the overhauling and making into reams. The standard quantity in a ream of printing paper is four hundred and eighty sheets, but paper is often put up with five hundred sheets in the ream, and

sometimes five hundred and sixteen, and also five hundred and twenty-eight, but in all these cases the number of sheets must be marked on the ream. The standard quantity for a ream of writing paper is four hundred and thirty-two sheets of whole, and forty sheets of broken, twenty of which must be above and below the whole.

VARIETIES OF PAPER.—The name *paper* comprehends a great number of kinds, differing very widely both in the mode of manufacture and in the purposes to which they are applied. They may, however, be all classed under four heads, namely, white paper, grey and brown paper, colored paper, and pasteboards of all kinds.

White paper includes two kinds, writing and printing, and of these there are various qualities. *Writing paper* stands at the head of this class, and the best quality is of a pure uniform color, strongly sized, and highly finished. There are many sorts of writing papers; but it will be sufficient to enumerate such of them as are best known by name to those who are unacquainted with the trade—such as cream, blue, and yellow, in color; laid and wove, in texture.

Cream is as nearly as possible a pure white. Writing shows always to most advantage on this color; but it has the defect of being more transparent than any other hue; and the high finish generally put on it increases the transparency. A small quantity of ultramarine and rose-pink improves the purity of this tint.

Blue is a fine shade, and has not the defect of transparency. It was formerly obtained by mixing a quantity of smalt with the pulp; but since the introduction of ultramarine smalt is not much used; ultramarine gives a much finer color, and is not so costly; and except in the sizing, where it occasionally causes some inconvenience, there is now no difficulty in employing it. When put among the pulp, both it and rose-pink should be well mixed in hot water, and strained twice either through a serge bag or the finest wire sieve, and should be put into the engine as soon as the chlorine is neutralized.

Yellow is simply a bluish shade given by using a smaller quantity of ultramarine than for blue; generally about a fourth or fifth part.

The old names given to paper are still retained, and also the sizes; but as the machine can make paper of any length, printing paper is generally cut to whatever size is most suitable for the printer.

The kinds of grey and brown paper used for wrapping are extremely numerous, and the varieties of colored paper are almost endless; but further details would be tedious to the reader, and would occupy too much space.

Formerly, paper manufacturers put a device, called the water-mark, on all their paper, and the old names, some of which are rather odd, are supposed to be derived from these devices. A jug or pot was put on paper of a small size; hence it still retains the name of *pott*. The fool's cap-and-bells was also one of their devices, and, although another mark has long been substituted, paper of that size also retains the name of *foolscap*. In like manner, *post* is supposed to have

been so called from the post-horn, which was at one time a common device. Besides these there were a great variety of marks, many of them of a fanciful kind, but which are now only interesting to the antiquarian.

Water-marks have frequently been of essential service as the means of detecting frauds in dating deeds, *et cetera*; and they are very useful on bank notes, cheques, and receipts. Those who are curious on this subject will find some amusing information in Mr. HERRING'S work on papermaking.

The following is a list of sizes of writing and printing paper. In a few cases there are two sizes in use, and both are given:—

	Inches.
Pott,	12½ by 15
Foolscap,	17 by 13½
Foolscap—writing,	16½ by 13½
Post,	18¾ by 15½ or 19 by 15½
Copy,	20 by 16
Large post,	20¾ by 16½
Medium post,	18 by 23 or 18 by 22½
Sheet and third foolscap, ..	24½ by 13½ or 22 by 13½
Sheet and half foolscap,	13½ by 25
Double foolscap—printing,	27 by 17
Double foolscap—writing,	16½ by 27
Double pott,	15 by 25
Double post,	30½ by 19
Double crown,	20 by 30
Demy—writing,	20 by 15
Demy—printing,	17¾ by 22½
Medium demy,	22 by 17½
Medium demy—printing,	23 by 18½
Royal—writing,	24 by 19
Royal—printing,	20 by 25
Super-royal—writing,	27 by 19
Super-royal—printing,	21 by 17
Imperial,	30 by 22 or 30½ by 22
Elephant,	28 by 23
Atlas,	34 by 26
Columber,	34½ by 23½
Double elephant,	26¾ by 40
Antiquarian,	53 by 31

The following is a list of coarse papers, such as grey and brown:—

	Inches.
Tient cap,	21 by 18
Bag cap,	19½ by 24
Havon cap,	21 by 26
Imperial cap,	22 by 19
Double two pounds,	17 by 24
Double four pounds,	21 by 30
Double six pounds,	19 by 28
Middle hand,	22 by 16
Lumber hand,	19½ by 29

Of purples there are—

Copy loaf,	16¾ by 21¾
Powder loaf,	18 by 26
Double loaf,	16½ by 23
Single loaf,	21½ by 27
Lump,	23 by 33
Hanbro,	16½ by 23
Titler,	29 by 35
Prussian, or double lump,	32 by 42

PAPER DUTY.—It would be out of place here to enter largely into the duty levied on paper; but any article on papermaking would be incomplete without some notice of it. It is usual to commence remarks on this subject by describing the annoyance and hindrance which the collection of this duty imposes on the paper manufacturer. On this point the Editor will not enlarge. The Honorable Board of Inland Revenue has for some years shown a more favorable disposition towards manufacturers than formerly; and has removed

and modified all restrictions complained of, so far as is consistent with the collection of the revenue and the protection of the honest trader. The officers of excise, also, generally give every facility in their power, and accommodate the manufacturer so far as their duty will permit. But the labor and much of the annoyance caused by the collection of this duty can only be removed by its total repeal.

This tax was first imposed in the year 1711. The law imposing it, and the regulations for its collection, have undergone many changes and alterations, which it is not necessary to particularize. When the duty was first imposed it was easily and to a great extent evaded; and manufacturers were not over scrupulous about the means of doing so. This naturally created a good deal of bad feeling between the manufacturers and those officers who acted honestly in the discharge of their duties. The expedients to which many manufacturers in former times resorted, and the indirect bribes which were given to excise officers, form a dark page in the history of papermaking; and it is a somewhat remarkable fact, that all those who resorted to these unworthy expedients have been ruined, and nearly all have been driven from the trade.

About the year 1800, the laws imposing the duty were revised, and paper was divided into three classes:—The first class comprised all paper made from rags, the duty on which was threepence per pound; the other two classes comprised all paper made from tarred ropes and all pasteboards, the duty on which was three halfpence per pound. In 1836 these laws were again revised; the division of paper into classes ceased, and a uniform duty of three halfpence per pound was imposed. A few years after this five per cent. was added to the duty; and under these laws the tax is still levied. This addition of five per cent. on the duty has been a heavier burden on paper manufacturers, and has been more complained of than the duty itself. It is a well-known fact that no corresponding advance was obtained upon the price of paper at that time. The additional five per cent. was, therefore, virtually a direct tax on paper manufacturers; and to show that this is not a mere trifle about which there should be no complaint, it may be stated that at a moderate computation a paper machine makes annually about seven hundred and fifty thousand pounds of paper, the duty on which is upwards of four thousand six hundred pounds sterling; and five per cent. on this sum amounts to upwards of two hundred and thirty pounds sterling. But with the exception of this sum the duty on paper is a burden on the consumer; and were the community alive to its baneful effect in diminishing the demand for labor it would have been repealed long ago. The Editor believes that all politicians now admit the impropriety of taxing the raw material of any manufacture. But paper is the raw material upon which a large portion of the population of the country is employed. Were it possible to trace it from the time it was a piece of dirty rag until it appeared as a highly-finished book, or an ornamented piece of papier maché, or an embossed envelope, it would be found very difficult to name any other material on which a greater amount of labor is bestowed.

The Editor conceives he is warranted in assuming that the repeal of the duty would greatly increase the consumption of paper, from the fact that the trade doubled itself in fourteen years after the duty was reduced to three halfpence per pound. This reduction took place, as already stated, in 1836. Now, in 1850, duty was paid on seventy million, six hundred and fifty-five thousand, two hundred and eighty-seven pounds; in 1850, on one hundred and forty-one million, thirty-two thousand, four hundred and seventy-four pounds—a great impetus having been given to the publishing trade, and to all those manufactures in which paper is used, which undoubtedly contributed to the prosperity of the country; nor should the fact be overlooked, that the reduction of the duty brought the means of obtaining useful information and rational enjoyment within the reach of the humblest classes of the community.

But, like all other evils, this duty has found defenders. One of the most plausible of their arguments is, that the excise regulations—which require that the weight to within five per cent. on paper above twenty pounds, and to within ten per cent. on paper below twenty pounds per ream, be written or printed on each ream—*gives security to the purchaser that he is not imposed on by a false weight.* One would suppose that a ream of paper could be weighed as easily as any other article, and any fraud of the kind at once detected. But the argument is altogether fallacious. Paper is sold not by the weight marked on the ream, but by the real weight; and if it exceeds the required weight, paper manufacturers lose the excess, and this is to them a source of considerable loss.

Another objection urged to the repeal of the duty is this—it is so small that its repeal would benefit only the paper manufacturers and printers, while the community generally would never derive any advantage from it. Let it be admitted that it would be a boon to papermakers and printers—it might be supposed that this would be an argument for and not against the repeal. It is difficult to see any justice in subjecting these classes in particular to an onerous burden, to which other merchants and manufacturers are not liable; and although the repeal of the tax would not lessen the expenditure of those who buy few books and no paper, yet even they and the entire community would be benefited by the increased demand for labor which would undoubtedly follow the extinction of this most impolitic impost.

STATISTICS.—IMPORTANCE OF THE PAPER TRADE.—The introduction of FOURDRINIER'S machine, and the application of steam power, with other improvements, have effected a complete revolution in the art of making paper, and have placed the trade among the staple manufactures of the United Kingdom.

Formerly paper-mills were spread nearly over the whole country, especially in England. Wherever there was a good stream of water, a paper mill was almost invariably to be found. These mills were generally small; *one machine will now make as much in one hour as some of them made in a day.* At that time, too, the trade was in the hands of a few wealthy firms, chiefly located in London, on whom paper manufacturers were to a great extent dependent. The exten-

sion of the trade, and the large amount of capital now invested in it, have to a considerable extent broken up that system; and the Editor believes that the firm of ALEXANDER COWAN and Sons, Valleyfield Mills, where the paper on which this work is printed is manufactured, was the first to adopt means to free itself from this virtual monopoly. In the year 1810 their mill there was one of the largest in Scotland, yet there was not produced then more than one thousand pounds of paper per day, or about fifty reams, whereas above four hundred reams are now made, the half of which is highly-finished writing paper. Some idea of the extent of these works may be formed from the fact, that there is made at an average every day forty miles of paper, five feet wide, or as much as would cover above twenty-four acres. The space required for finishing the paper covers nearly one thousand three hundred square yards, or something more than one-third of an acre, and above seven hundred people are employed.

There has, perhaps, in no locality been a greater extension of the trade than on the river Esk, on which these mills are situated. At the close of the French war, in the year 1815, twenty-six vats were in operation, the produce of which would not exceed four thousand five hundred pounds of paper per day, and the number of people employed could not be more than four hundred; there are now on that river fifteen

machines at work, the produce of which is not less than thirty thousand pounds per day, and the number of people employed amounts to about two thousand.

The subjoined statement, derived from sources of undoubted veracity, will show the extension of the trade generally. In the year 1784 the value of paper made in the country was estimated at eight hundred thousand pounds, the duty on which was forty-six thousand eight hundred and sixty-seven pounds sterling; in the year 1856 there were charged with duty, one hundred and eighty-seven millions, seven hundred and sixteen thousand, five hundred and seventy-five pounds sterling. The duty on this would amount to one million, two hundred and thirty-one thousand, eight hundred and eighty-nine pounds; assuming the value of paper at an average to be about three times the amount of duty, the value charged with duty in that year would amount to three millions, six hundred and ninety-three thousand, six hundred and sixty-seven pounds sterling. The number of people employed in the direct manufacture of paper is supposed to be about thirty thousand; but, besides this, there are thousands who find occupation in making and repairing the machinery used, and also in preparing the chemical substances required in the manufacture.

The annexed table exhibits the quantity of paper in the United Kingdom charged with duty, exported, and retained for home consumption during ten years:—

	1847. Pounds.	1848. Pounds.	1849. Pounds.	1850. Pounds.	1851. Pounds.
Charged with duty,	121,965,315 ..	121,820,229 ..	132,132,660 ..	141,032,674 ..	150,903,543
Exported,	5,852,979 ..	5,180,286 ..	5,966,319 ..	7,762,686 ..	8,305,590
Home consumption,	116,902,336 ..	116,639,943 ..	126,166,341 ..	133,269,988 ..	142,597,943

	1852. Pounds.	1853. Pounds.	1854. Pounds.	1855. Pounds.	1856. Pounds.
Charged with duty,	154,469,211 ..	177,633,009 ..	177,896,224 ..	166,776,234 ..	187,716,575
Exported,	7,328,886 ..	13,296,874 ..	16,112,020 ..	11,110,924 ..	14,798,979
Home consumption,	14,710,325 ..	164,336,135 ..	161,784,204 ..	155,665,310 ..	172,917,596

The following table shows the quantity of paper respectively, during the years 1855, 1856, and nine months of 1857:—

	1855.	1856.	Nine months of 1857.
England,	123,552,869	139,752,062	109,660,884
Scotland,	35,932,985	40,100,234	31,925,920
Ireland,	7,290,380	7,864,279	6,081,269
Total,	166,776,234	187,716,575	147,668,073

These figures prove the expansion of which the trade is capable; but however important the paper manufacture may be as a source of national industry, it is justly entitled to a higher place than that which belongs to it merely in this material aspect. There is no article so intimately connected with *mind* as paper—none upon which the development of the moral and intellectual nature of man is so dependent; and mankind is now learning how much the welfare of the race depends on the right cultivation of the mind. It is now universally admitted that in a densely-populated country there is no permanent security for life, property, and progress, unless the whole mass of society is leavened with the rudiments of knowledge and the principles of morality. For this purpose paper is essentially requisite. It would be vain to speculate with regard to the future, but it is evident that paper must

be the medium of diffusing the blessings of knowledge and Christianity throughout the world, and is destined to be one of the most powerful agents, under Divine Providence, in renovating the human family.

PERFUMERY.—*Parfumerie*, French; *parfümerien*, German.

By nature's swift and secret working hand
The garden glows, and fills the liberal air
With lavish odors.—*Thomson*.

The distinction between perfume and odor is substantial as well as critical—the former designating those volatile emanations which are usually considered agreeable, while the latter, in its general signification, is applicable to every scent, irrespective of its nature. GREGGIO, in *The Taming of the Shrew*, directs that the papers he sends to BIANCA may be *well perfumed*, for she is *sweeter than perfume itself*; while, in *King John*,

SHAKESPEARE makes CONSTANCE call death *thou odorous stench*. Of the five senses, that of smelling is the least valued, and, as a consequence, is the least tutored; but from this one must not conclude that it is of insignificant importance to the welfare and happiness of mankind.

By neglecting to tutor the olfactory nerve, one is constantly led to breathe vitiated air, and thus poison the body by neglecting the warning given at the gate of the lungs. Persons using perfumes are more sensitive to the existence of a vitiated atmosphere than those who consider the faculty of smelling as an almost useless gift.

HISTORICAL NOTICE.—There is no delicate luxury which has held its influence so long and so uninterruptedly upon refined society as that of perfumes; and their annals comprise the history of the folly, voluptuousness, and extravagance of past ages. The antiquity of their use is very great, and one is almost lost in searching for their origin.

Perfumes seem to have been first imported from Elam, now called Persia, and they were important articles of commerce between that country and Egypt. The distant deserts were often traversed by camels laden with *odors of sweet scents*; and when the Ishmaelitic merchants, to whom JOSEPH was sold, were going to Egypt, they were wending their way with *spices and balm and myrrh*. At a later period, but long before the time of CONSTANTINE, the Turks were accustomed to lubricate their persons with fragrant unctions, to complete the gratefulness and value of their baths. MOSES was commanded to speak unto the children of Israel, that in the offerings of the tabernacle they should bring *sweet spices*, and *anointing oil*, with *sweet incense*; and that they should make of the former *a perfume, a confection after the art of the apothecary, tempered together, pure and holy*.

Indeed, perfumes were considered among most of the ancients as necessities of life, and entered into nearly all their ceremonies of a religious or social nature. They were used both at feasts and at funerals, and were burned as well in honor of the living as of the dead. The priests of Memphis offered them as incense, daily, to the sun; and the Egyptians, by their aid and with resins, have transmitted their illustrious dead, in mummies, through thousands of years to living generations.

As in the Mosaic days, spices and frankincense were held as sacred offerings to the Lord of Hosts, so in the new era of religion the practice was not discontinued, and CHRIST after crucifixion was embalmed in spices; but at first, it seems, that certain spices were devoted only to religious uses, for EZEKIEL accused the Jews of profanity in applying to their own purposes the odors which were reserved for sacred things; and ISAIAH reproaches them as faithless to God, and as like a spouse painted and perfumed to please strangers.

The present mode of introducing flowers at repasts was common among the Grecians and Romans. Rich perfumes and precious ointments were among the treasures found by ALEXANDER in the camp of DARIUS, and thus, possibly, the Greeks borrowed the example of their use from the Persians. The violet was most grateful to the Athenian taste, but every part of the

body had its appropriate perfume; the oil extracted from the palm was thought best adapted to the cheeks and the breasts; the arms were refreshed with balsam mint; sweet marjoram supplied an oil for the hair and eyebrows; and wild thyme for the knee and neck. Perfumes, in time, became very common among them. The *nardus* and *malobathrum* were held in much estimation, and were imported from Syria. The *baccaris*, the *brenthium*, the *psagda*, the *plangonium*, and the *sagdas*, made principally of the general constituent of all the ancient ointments, *videlicet*, myrrh, had their respective eulogists. The saloon, where any entertainment was given, was generally perfumed by burning myrrh or frankincense in it. A nice distinction divided perfumes into two kinds: the first were of a thicker sort, and applied more as salves, or wax; the latter were liquid, and poured over the limbs. To indulge in the liquid ointment was considered as effeminate and voluptuous, but the sober and the virtuous were permitted to use the thicker variety without any impeachment of their good qualities. The supplies of perfumery occupied a considerable place in the stock of those artisans who contributed to the embellishment of a Grecian lady of fashion. The article itself bore a high price, but this did not hinder voluptuaries using it profusely, not, however, without an occasional admonition from the grave men of the misbelief arising from its abuse. The old people referred to a statute of SOLOON, forbidding the sale of perfumery, at least by the male sex; SOPHOCLES significantly described VENUS as sprinkled with perfume, and looking in a mirror; and PALLAS, the goddess of wisdom, as moist with olive oil, and practising the exercises of the palaestra. SOCRATES objected to the use of perfumery altogether. There is the same smell, said he, in a gentleman and a slave, when both are perfumed. In his opinion, the only odors worth cultivating were those arising from honorable toils and the smell of gentility.

A knowledge of perfumes soon extended from Greece to Rome; and the abuse in the employment of them was such that PLINY lamented their introduction into the camp. NERO is said to have consumed in the funeral pile of his wife, POPPEA, more incense than could have been produced from the whole of Arabia in a year; and under the consulate of SUCINIUS CRASSUS, in order to secure a sufficiency for church purposes, a law was necessary to restrict the use of them to that and a few other special objects.

With the decline of the Roman Empire, the European commerce in perfumery diminished; and in the disastrous epoch of Vandalism, when floods of barbarians inundated the capital of the world, refined taste took its flight, and perfumes became obsolete. In modern days, however, civilization revived, and brought back with it this one of its concomitants, which was soon nurtured into a vigorous growth, upon the institution of a new era of gallantry and elegance. The supremacy of woman's influence being thus re-established, perfumes, as aids to beauty, were in constant and extravagant demand.

In the reign of LOUIS the Fifteenth, the ladies at court indulged most freely in perfumes, and fashion ordained an ever-varying routine; so that the royal

apartments were one day fragrant with the scent of the tuberose, and the next with that of amber and cloves; and so on, consecutively, each succeeding day bringing a change of the reigning odor. In that luxurious age, the personal use of perfumes was not confined to the fair sex, but the effeminate gallants and *petit-maitres* of the day gloried in perfuming themselves with the favorite scents of their mistresses or of presiding belles; so that allegiance was recognized, not, as in more chivalrous times, by the knight wearing the colors of the fair one who had enslaved him, but by his smelling of the particular odor which she had consecrated to herself.

Pathologically considered, the use of perfumes is in the most eminent degree prophylactic; the refreshing qualities of the citrine odors to an invalid is well known. Health has often been restored when life and death trembled in the balance, by merely sprinkling the essence of cedrat in a sick chamber.

Throughout all civilization, from the dim early ages to the enlightened days of the present—through every ramification of society, and in all the sacred ceremonies of life—flowers and perfumes have ever borne a conspicuous part, and by their graces and freshness, touching allegories and seducing sweetness, blended themselves with the pleasures and hopes of mankind; sometimes typifying transient images, but still, *also*, appearing as the beautiful symbols of those affections and principles which are *most enduring*.

SOURCES.—Perfumes are derived from a variety of natural sources; a few being of animal origin, and the remainder emanating chiefly from the vegetal kingdom. In their primitive state of isolation, they may be termed *simple*, in contradistinction to the *compound* odors, which are made up by combinations of the former, varied according to the taste and skill of the manufacturer. In this way an infinite variety of scents may be obtained. But the art of the perfumer is not wholly restricted to the preparation of odors; it extends also to the fabrication of pomades, aromatic vinegars, washes, tooth powders, cosmetics, fine soaps, and all appliances of the toilet which by their tonic, emollient, or cleansing properties, will improve the health and beauty of the skin, hair, and teeth. In some of the preparations, certain *mineral* matters enter as ingredients to impart color or consistence; and but rarely for any purpose otherwise connected with the efficiency of the product. In all instances, however, the smell is most important. When the perfume does not exist in a free state, it is then manufactured from the raw material by mechanical or chemico-mechanical means; as, for instance, by expression, distillation, maceration, infusion, and enfleurage, as will be more fully explained hereafter in treating of the essential oils, extracts, fats, waters, *et cetera*.

In enumerating the raw materials used in the manufacture of perfumery, it will not be possible here to give more than the striking properties and characteristics of each. These will, however, suffice to convey the necessary information for making a judicious selection; and it is only necessary to add that the purity of the *stock*, and the manner in which it has been gathered and kept, have an important bearing upon the quality and quantity of the products to be obtained from it.

ANIMAL SUBSTANCES.—The *perfume*-materials of this class are only three, and each is an animal secretion: namely, musk, civet, and ambergris.

Musk.—This exists in the excretory follicle behind the navel of the adult male of the *moschus moschiferus*, or musk deer, of Siberia, Thibet, China, and other mountain ranges. These bags, or *pods*, as they are termed in commerce, contain from two to three drachms of musk. When separated from the sack, it is called *grain musk*. Tongva musk outranks all others in quality, and that from Russia is the most inferior. Thibet musk is of intermediate quality. The high price of this substance renders it liable to adulteration with dried blood, brown earth, *et cetera*. The finer grades are frequently weighted by the fraudulent introduction of pieces of lead into the pods. To test the quality of musk, plunge into the pods a wire which has been rubbed with garlic, and then note the odor. If the garlic odor is disguised by the musk, the latter may be considered of good strength.

Musk, from its pleasantness and permanence, becomes a general basis-odor; and from these, and its diffusibility, it may be called the wings of the perfumes, as, besides carrying with it the other fragrances, it survives to pronounce their departure and illustrate its own durability. It requires, however, to be very much diluted, in order that it may not prevail too much in the scents which may contain it as an ingredient.

Civet.—The secretion of the civet cat, or *viverra civetta*; also, of the *viverra zibetha*. It is scraped out from the glandular receptacle near the anus, and sent to market in small bags made of the skin of the animal. The supply comes mostly from Malabar and Bassord. It is of a pale yellow color, and has a musky odor of such intensity as to be offensive, except in a highly diluted state. Its admixture in small proportions with other perfumes gives agreeable modifications, and imparts strength and permanence.

Ambergris.—So called from *amber-gris*—grey—because of its having been considered by some of vegetal origin, and analogous to amber. It is more probably a bezoar from the whale, and may be a product of disease. It is found floating on the sea, near the coasts of China, Japan, Coromandel, Brazil, Ireland, and America. It is in small irregular masses of scaly fracture and grey color, with yellow, and sometimes black streaks. It emits a very peculiar and diffusive smell of great power, and is largely used in admixture with more feeble and less persistent odors.

Spermaceti.—A beautiful, pearly-white, dry, inodorous fat, found in the bony receptacles of the head of the white whale—*physteter macrocephalus*. It is obtained by subjecting the head matter of the whale to hydraulic pressure, for the separation of the oily portion. Unless entirely freed from oil, it is liable to become rancid. It may be purified sufficiently by subjecting it repeatedly to hot pressure; or, more expensively, by dissolving out the oil with boiling alcohol. Its structure is scaly, and it may readily be crystallized in plates. When pure, it melts at 120°. *Solar spermaceti* is the popular name of an admixture of true spermaceti with palmitic acid.

Spermaceti has eminent emollient properties, and is

used in perfumery as an ingredient of pomades, creams, cosmetic pastes, and the like.

Wax.—This is the solid portion of the honeycomb, produced by the hive bee—*apis mellifica*. In its native state it is yellow, or brown-yellow, and sometimes grey; but it can be bleached perfectly white by chemical means, or by exposure, in thin ribands, to the combined action of light, air, and moisture. It is the white wax which is most generally used by the perfumer; and that bleached by the latter method is the best, as it is purer, firmer, and drier; moreover it is tasteless. Pure wax melts at 149°. It is often adulterated with earthy matters and stearic acid. The first shows itself when, on melting the wax, an infusible and insoluble substratum remains. The last is known to be present if effervescence and a gelatinous solution are produced by boiling some of the wax in distilled water, containing one-fiftieth of its weight of carbonate of soda. There are also several kinds of vegetal wax assimilating to beeswax in physical character, but they have not yet been employed in the art of the perfumer.

Suet.—As found in commerce, suet is generally a mixture of beef tallow and mutton fat. It is *rendered* by heating the *rough fat*, and pressing it, to separate the membranous matters. When of good quality it is firm, and does not melt below 98°.

Suet and lard form the body of pomades; and that the quality of these latter may be unexceptionable, the fat material must be perfectly fresh, inodorous, and pure. The rendered suet being almost always more or less deficient in those respects, it must, therefore, be subjected to a purifying process, in order to fit it for use in perfumery. This is done by melting the fat by the heat of a saline or steam bath, in an enamelled iron vessel, and adding to it, gradually, powdered alum and chloride of sodium, in the proportion of one ounce of the former, and two ounces of the latter, to every fifty pounds of fat under treatment.

The heat is to be continued above 212°, until scum ceases to rise to the surface, which contains all the organic and other impurities, and must be removed with a skimming ladle as fast as it is formed. The fat is then to be strained through bolting cloth into clean stone jars, and there left to cool. It is next to be spread upon a circular stone slab, with its top surface slanting from the centre, over which a stone roller is made to move by suitable gearing. As the roller, or muller, as it may be called, revolves over the fat, cold water is allowed to trickle upon it, and this latter acts by dissolving out the saline and organic impurities, and in flowing off carries them away. This treatment is continued until the fat is free from foreign matters, after which it is to be melted, and heated, as before, until all retained water has been expelled by evaporation. When cold, the fat will be found to be very white and pure, and in a condition to preserve its sweetness. In this deodorized state it is suitable for use with the most delicate odors. An apparatus like that described under DYEING, Vol. I., page 703, will be very suitable to carry out the process just described.

Lard.—This is the fat of the common hog, and that kind commercially known as *corn-fed lard* should be selected, as it is superior to other grades in many

respects. Though fine and white, it is softer and more fusible than suet. It melts at 81°. The lard used for perfumery should be pan-rendered, over an open fire, or by *dry steam*; for if *wet steam* is used, and under pressure, as is most generally the case, then it contains foreign organic matters in solution, which give it a tendency to decomposition, and cause it to emit a disagreeable smell. Moreover, it is then granular, instead of being smooth in body. To give it a condition suitable for the perfumer, it must, however, be carefully rendered, and undergo purification in the same manner as directed for suet.

Both lard and suet are used as *body* for pomades; the former constituting *soft body* for winter climates, and the latter *hard body* for summer temperatures.

Suet and lard are described also in Vol. I., page 413, to which the reader is referred.

Bears' Grease and Beef Marrow.—The fat of the common bear is soft, and not unpleasant in odor when carefully rendered. It is a favorite grease for the hair, and for that purpose, as well as to cheapen it, is often mixed with marrow obtained from the *marrow bones* of beef cattle.

COLORING MATTERS.—It is often desirable, as a matter of taste, to tinge these bodies; and the process to be followed for them, and also for other fats, whether solid or fluid, is as follows:—

Alkanet root is the coloring matter for imparting a *pink* shade, and four ounces are required for every pound of fat. The fat having been melted over a water bath, the bruised root is then added, and the whole digested at a moderate heat for several hours. The mixture is then strained through bolting cloth, and the clear fluid fat, now colored deep pink, allowed to cool; and this may be termed the tinctorial substance. One ounce of this highly-tinged body will suffice to impart a hue to a pound of fat; and the manipulation consists in simply melting the two together, by gentle heat, in an enamelled pot. *Yellow* coloring body is similarly made with annotta, in the proportion of one ounce to the pound of fat. To give a *green*, fresh walnut leaves may be used. A *brown* shade may be obtained by merely adding a few drops of *caramel* to the melted fat, and continuing the heat until the water which held the caramel in solution has evaporated. Color may be imparted also by the addition of pigments in powder, but these latter are objectionable for pomade body, hair oils, and creams.

Cochineal.—This is a small wrinkled insect—*coccus cacti*—indigenous to Mexico and New Spain, which feeds upon several species of cactus. After having been scraped from the leaves, it is scalded, and then dried in the sun. The best is that which presents a silvery white exterior. Cochineal gives a brilliant crimson powder, and is used in that way as a coloring matter. A *liquid scarlet* may be made from it by boiling, say one ounce in eight ounces of distilled water, for fifteen minutes, and then adding thirty grains of powdered alum, and then reboiling for three minutes, and straining through bolting cloth. *Carmine*, the brilliant red used so extensively as a finer color for rouges, powders, &c. *cetera*, is made from cochineal. It is soluble in aqua ammonia, and, thus treated, it forms the solution called *liquid carmine*, or carmine ink, which also has a wide

range of application in the manufacture of perfumery. Carmine is prepared on a large scale by the practical chemists, and of various qualities. French carmine is considered the best.

VEGETAL SUBSTANCES.—The art of perfumery is almost wholly dependent for its existence and success upon the botanical kingdom; as the simple odors, with very few exceptions, come exclusively from that source. The only peculiarity in this respect is, that the plants growing in tropical latitudes are more prolific in odor than those of Northern climes. The East Indies, Ceylon, Peru, and Mexico, afford rich supplies of their indigenous stock; and nearer home, the South of France, bordering on that part of the Mediterranean between Toulon and Nice, is almost entirely cultivated for the production of perfume materials. Grasse and Cannes are the two principal flower gardens; and the genial, equable climate of this region renders it peculiarly favorable for the purpose to which it is devoted. To the enterprise and skill of their inhabitants the world is indebted for many of the finest and best perfumes, and they in return derive a large revenue from the trade.

The odor of a plant is due to a highly volatile matter, which is most generally an oil, called the essence or essential oil. In some instances, however, the odor is a very delicate and ethereal principle, and, therefore, not in a tangible form, though very evident to the sense of smell. In this latter case it is extracted and fixed through the agency of a medium substance, as will be explained under the head of pomades. The odors, though every odor is not necessarily fragrant, exist already formed in the living plant, or else are generated, as in the instance of bitter almonds, by some reaction between the elements, which takes place during fermentation or distillation. It is generally secreted in little sacs or vesicles, and so well confined that it does not escape in many cases even during the drying of the plant, if it be carefully done, whilst in other plants again, the aroma is being constantly produced at the surface, and as constantly exhaled at the moment of formation. The organism of the plant, and its vital force, are the creating power.

The aroma exists in every part of plants, but not in all portions of the same plant. Sometimes it is obtained from the root or wood, then from the bark, and again from the flowers, leaves, fruit, or seeds. Some few plants yield odor in all their parts. The orange gives three distinctive odors—*oil of neroli* from the flowers; *essence of Portugal* from the rind of the fruit; and *oil of petit-grain* from the leaves; and thus it appears that the oil may also differ with the part of the plant whence it is obtained.

The resinous and balsamic exudations of plants, such as benzoin, and myrrh, and the like, are often impregnated with the aroma of the plant.

The scents of plants are extracted in the form of oils, or attars, extracts, fragrant waters, *et cetera*; and the skill and taste of the perfumer render them capable of being infinitely extended and diversified by combination. In this way the great variety of *bouquets* have their origin.

There are many substances of vegetal nature also used largely in the art of perfumery for other purposes than as scents. For obvious reasons the Editor must

restrict the notices to those which are the most important; and for the better understanding of the subject, will classify them into roots, woods, leaves and flowers, seeds, balsams and resins.

1. **ROOTS.**—These yield their aroma by distillation with water, in the form of essential oil, or scented waters. They may also be used in powder.

Angelica—from the garden, or *a. archangelica*. The tops of the flowers are also serviceable. The root is spindle-shaped, greyish-brown, and much wrinkled externally, and whitish and spongy within when dried. Its fragrance is due to a volatile oil.

Calamus, or *Sweet Flag*—is the root-stem of the *acorus calamus*, and comes in long, slender pieces, with a yellowish-brown and wrinkled exterior. It is white in the interior, and gives off an aromatic odor, which may be obtained in the form of volatile oil.

Ginger.—The root of the *amomum zingiber*, growing in the East and West Indies, and Mexico, enters into the combination of many aromatic waters, and several kinds of dentifrice. The *white* ginger of Jamaica is considered the best, being the selected roots deprived of their epidermis. It gives a yellowish-white powder, and emits a penetrating aromatic odor. A volatile oil may be separated by distillation, but this property is generally and more readily extracted in the form of a tincture, by macerating the root in alcohol.

Orris, or *Iris*.—The white, fleshy part of the root of the *iris florentia*, which is native to Italy, and cultivated in the South of Europe. It comes in pieces of irregular form and size, which, being brittle, are easily reduced to powder. It emits an odor assimilating to that from violets, but very much inferior. The powder enters largely into the composition of tooth and sachet powders, for the purpose of giving volume as well as odor. Its tincture, made by digesting one pound of the powder in one pint of alcohol for two weeks, and filtering, is used to give body to more feeble perfumes, and improve the fragrance of those which are deficient in that property.

Souchet.—The root of the *cyperus longus*, and emits an agreeable, violet-like odor. It is generally macerated in acetic acid, then dried and reduced to powder.

Vitiver, or *Kus-kus*.—The fleshy part of a species of dry grass from India. It has an aromatic odor, and is used in the same manner as *orris* root. The tincture or extract of *vitiver* is made by digesting one pound of the dried root in a quart of alcohol for two weeks, and filtering. This tincture was formerly much used in bouquet combinations, and was an important ingredient in the once celebrated preparations of that kind called *mousseline des Indes*, *bouquet du roi*, *et cetera*. By distillation, it yields about one per cent. of volatile oil called *otto of vitiver*, and resembling, according to *PIESSE*, the *otto of santal*.

2. **WOODS.**—Those which are used as scents yield their odors by distillation with water, or by digestion in alcohol or other solvent. They are also used in powder, and several of them merely as coloring matters.

Aloe.—There are three varieties of this wood, and all come from China; namely, first, *calambac*; second, *agallochium*; and third, *aigle* or *gare*. The first is very rare and high-priced, being used only for fumiga-

tions in temples; is brownish-red, resinous and heavy, and emits in burning an aromatic odor. The *agal-
lochium* is orange-colored, has a waxy fracture, and an odor less myrrhine than the *calambae*. This is the kind usually found in commerce. The *aigle* or *garé* wood differs from the other two in having a greenish-yellow color and musky odor, and also in not being bitter. It is fibrous, sometimes spongy, and, when burned slowly, eliminates an agreeable aroma. The latter two are used as ingredients of fuming pastilles.

Brazil.—The chipped wood of the different species of the *casalpinia* growing in Brazil and the West Indies. That from Pernambuco is the hardest and best. When freshly cut it is light reddish-brown, but on exposure becomes of a brighter tint. It is used as a cheap tinctorial matter, and forms the material whenc the lakes are made. Its color may be extracted in soluble form, by boiling four ounces of the wood in a quart of water containing one drachm of chloride of tin, and filtering.

Cascarilla.—The bark of the *c. gratissimus*, as well as that of the *c. fragrans* and *c. fragilis*, are used as ingredients of fuming pastilles. The first is a component of the *eau à bruler*, for perfuming apartments, and is the most fragrant and valuable of the three kinds. Its leaves, according to PIÈSSÈ, are gathered by the Koras of the Cape of Good Hope as a perfume.

Cassia.—The outer bark of the *cinnamomum cassia*, and the Chinese cinnamon, from Canton. It yields, by distillation, about three-fourths of one per cent. of volatile oil, of aromatic rather than flowery odor, and much used for mixing with other perfumes, and for scenting soaps.

Cedar.—The wood of the cedar emits an agreeable odor when burned, and on that account is sometimes made into sticks for lighting lamps. In a finely-ground state it may be employed as a body for sachet powders, for it is said to keep away moths. It gives on distillation a fragrant volatile oil, occasionally used for scenting toilet soaps. The wood forms a crimson-colored tincture with alcohol, and may be thus employed to tinge and scent tooth-powders.

Cinnamon.—The bark of the *laurus cinnamomum*, and that from Ceylon is the best. It is very thin, brownish-red, and has an agreeable aromatic flavor. The cassia, which it resembles closely, is thicker, rougher on the surface, and comes in larger rolls or quills. The first is often sophisticated with the latter, and sometimes even a part of its volatile oil is abstracted by infusion in alcohol. This latter fraud is detected by the feeble smell and taste of the cinnamon. The finely-ground bark is used for pastilles, sachets, and tooth-powders. Its aroma may also be extracted in the form of tincture, by alcohol. By distillation, it yields an essential oil of powerful odor, which is largely used in combination with oil of cloves and other strong essences.

Clove.—This bark, known also by the name of *cannelle giroffée*, and *bois de crabe*, is brought from the West Indies. It comes in concentric cylinders of about two feet length and an inch diameter, and has a dark-brown color. Its aromatic flavor, though similar to that of cloves, is much weaker.

Guaiacum.—This wood is imported from the West Indies. It is hard, compact, and resinous, and when burned or rubbed emits an agreeable odor. It enters into the composition of odontalgic liquors.

Rhodium.—Called also *rose wood* and *cyprus wood*; and incorrectly, by the French, *jacaranda*. It is the wood of the *convolvulus scoparius*, and has a pale-red color, and slightly bitter taste. It emits an agreeable perfume, and is used when ground for scented powders. When distilled it yields a sweet-smelling oil, but this latter is seldom used, being superseded by the oil of geranium.

Santal.—This grows in the island of Timor and the Santal Wood Islands, and is improperly called *sandal wood*. It is extensively employed by the Brahmins, Hindoos, and Chinese, as incense in their religious ceremonies. Its strong, agreeable, and peculiar odor is very offensive to ants, and renders it a good material for cabinet ware. By distillation, it yields attar of santal, which is dense and oily, and has a dark straw color. It is often used in the form of extract, or tincture, made by dissolving one ounce of the attar in three pints of rectified alcohol, and adding four ounces of essence of rose. CAMERON writes of this scent as follows:—

The santal tree perfumes, when riven,
The axe that laid it low.

Sassafras.—The bark of the *laurus sassafras*, and is used in the form of tincture made by digesting it in alcohol. It also affords a volatile oil, but its odor is not delicate. It is employed for perfuming the coarser grades of transparent soap, and for admixture with other strong and common odors, to modify and improve their intensity.

3. LEAVES AND FLOWERS.—The leaves and flowers are when in a fresh state, of much greater advantage than after being dried. Indeed, very many are not serviceable for the extraction of their perfume, except when recently harvested. Drying is only resorted to with certain kinds for exportation, and this process must be carefully conducted in air chambers, to which the sun has access in summer. In winter, a gentle heat is necessary. The flowers or leaves are placed upon wicker waiters, and require to be stirred occasionally, in order that new drying surfaces may be presented, and fermentation hindered. In Grasse and Cannes the harvest is gathered by itinerant agents, called *commissionaires*, in the employ of the growers, and through them the product is sold to the distiller and perfumer. The harvest takes place at the flowering time of the plant, in a dry season, and towards the noon of the day, after the dew has evaporated.

Balm.—The leaves of this herb—*melisia officinalis*—yield, by distillation, a volatile essence, sometimes called the oil of melissa. It has a peculiar, fragrant odor, but is seldom used. The leaves lose their fragrance, in a great measure, when exsiccating.

Cassie.—The flowers or buds of the *acacia farnesiana* yield a very intense, but delightful odor, resembling that of violets, and much used in compounding fine scents for the handkerchief. The process of infu-

sion must be employed for its extraction and preparation. It is cultivated extensively at Cannes. DRYDEN, in his *Virgil*, thus alludes to it:—

The short narcissus and fair daffodil,
Pansies to please the sight, and *cassie* sweet to smell.

The *Wattle*, a plant of the same genus as the foregoing, and which grows luxuriantly in South Australia, yields, according to PLESSÈ, a very similar perfume.

Citrou.—The flowers of this plant—*citrus medica*—give, by distillation, a fragrant oil, which is much in demand for the manufacture of Cologne-water.

Citrouella.—This is supposed to be one of the grasses of the *andropogon* genus. The oil comes from Ceylon and the East Indies, and its odor resembles that of the oil of citron fruit. It is comparatively inexpensive, and forms the perfume of the so-called honey soap.

Elder.—The flowers of this plant—*sambucus nigra*—have a peculiar sweetish odor, and are used for preparing, by distillation, the elder flower-water. This latter enters into the composition of several cosmetic creams, milks, and oils.

Fennel.—The common fennel herb—*feniculum vulgare*—has an aromatic odor due to the existence of a volatile oil, which is used in combination with other oils for scenting soap. The herb itself, when dry and ground, is used in certain sachet powders.

Geranium.—The leaves of the rose geranium—*pelargonium odoratissimum*—are very largely cultivated in Grasse and Cannes for their essential oil, which is obtained by distillation. The plant also grows abundantly in Turkey. The odor of the oil is very agreeable and rose-like, and the color varies from white to brownish, and sometimes greenish. The oil of the *andropogon nardus*, cultivated in the Moluccas, is often used, according to PLESSÈ, for adulterating the oil of rose-geranium. The delightful odor of the true oil of geranium renders it a useful perfume. It is also used extensively for adulterating otto of rose, than which it is much less costly.

Heliotrope.—The aroma of this plant—*h. peruvianum* and *h. grandiflorum*—resides in the flowers, and is obtained either by infusion or enfleurage. The flowers must be subjected to treatment in their fresh state, and immediately after being gathered. The odor is suggestive of that given by almonds and vanilla combined; and its exquisite fragrance adapts it to the production of the finer kind of compound scents.

Honeysuckle.—This flower, also called woodbine—*caprifolium perfoliatum*—is of luxurious growth, and yields a delicious odor by the process of enfleurage. The poet COWPER thus speaks of it:—

Copious of flower, the woodbine, pale and wan,
But well compensating her sickly looks
With never-cloying odors.

Jasmine.—This plant—*jasmine grandiflora*—is the *yasmyn* of the Arabs. The jessamine flowers in July and August, and is extensively cultivated in the Southern part of France. The essential oil may be obtained by distillation; but as its production is very costly, and the yield very small, resort is generally had to the process of enfleurage for the extraction of the

aroma. This odor is peculiar, but richly fragrant, and enters into the composition of many of the finer scents for the handkerchief. The poet says—

Luxuriant above all,
The jasmine throwing wide her elegant sweets.

Jonquil.—The flowers of this plant—*narcissus jonquilla*—give out an agreeable odor, which may be extracted by the process of enfleurage.

Lavender.—This plant, the common lavender—*lavandula vera*—is one of the most renowned of antiquity, being the spikenard of the ancients. It was then only less employed as a medicament than as a perfume. It is still an ingredient of some few medicinal preparations. Its extensive use in washing and bathing is the origin of its present name, from the Latin word *lavo*, to wash. The plant grows in the Southern parts of Europe, and is largely cultivated at Mitcham in Surrey. The British lavender is the most fragrant, and brings four times the price of that from the continent. By distillation, the flowers yield an essential oil, and also *lavender water*. The sweetness of this perfume and its abundance render it very serviceable.

The French lavender—*l. spica*—also yields a fragrant oil and water by distillation; but they are very far inferior to those from the preceding species. The oil of this latter plant is called the *oil of spike*.

Lemon Grass.—A species of grass, said to be *andropogon schoenanthus*, which grows abundantly in India, and is largely cultivated in Ceylon and the Moluccas. By distillation, the plant yields an essential oil, assimilating in odor to that of the oil of lemon, and sometimes called *oil of verbea*. This perfume is very agreeable and economical, and well adapted for extensive use, either alone or in combination with other scents.

Lilac.—The flowers of this shrub—*syringa vulgaris*—are very fragrant, and yield a perfume by the process of enfleurage, resembling that from the tuberose.

Lily.—The lily of the valley—*lilium candidum*—bears flowers which emit a peculiar and powerful fragrance. This aroma may be extracted by the process of enfleurage; but eight or ten repetitions, with the same fat or bearsoil and fresh leaves, are required to obtain the requisite strength.

Magnolia.—The flowers of this plant—*m. glauca*—are strongly and gratefully odorous. It abounds in the swamps of the Middle and Southern states of South America; and is sometimes called white bay, sweet bay, *et cetera*. The aroma is extracted by the process of infusion or enfleurage.

Marjoram.—A species of thyme—*origanum marjoram*. This herb yields, by distillation, a strong scented essential oil, much used for perfuming soaps. It is called *oil of orangeat* by the French.

Meadow Sweet.—This plant—*spiraea ulmaria*—affords a sweet-smelling oil by distillation.

Mignonette.—This plant—*reseda odorata*—is widely cultivated in Grasse and Cannes for its flowers, which are characterized by a peculiar and very delicate fragrance. The odor is extracted by the process of enfleurage; and to give it consistency, the extract is generally mixed with a little violet.

Mint.—The herb—*mentha viridis*—called spear-mint, yields, by distillation, a strong-smelling aromatic oil, which is much employed in mouth-washes; and also as an ingredient of compound perfumes for soaps.

Myrtle.—The flowers and leaves of the common myrtle—*myrtus communis*—yield, by distillation, a very fragrant oil. Myrtle-flower water is sold in France by the name of *eau d'auge*.

Neroli.—There are two species of the orange; the Portugal or sweet orange—*citrus aurantium*—and the bitter or Seville orange—*citrus bigaradia*. The flowers of both give very fragrant essential oils and waters by distillation; but those from the latter are the most costly and best esteemed. The oil is called oil of neroli; the water, orange-flower water. The leaves and unripe fruit of the bigaradia also give a volatile oil by distillation, known as essence of petit-grain. The essential oil distilled from the rind of the fruit of the sweet orange, is called essence of Portugal.

All the neroli products are highly esteemed for their delightful odor, and enter largely into the composition of perfumes, particularly that of the savine Cologne water, and other fine bouquets for the handkerchief. The essence of petit-grain is mostly used for scenting toilet soaps; and orange-flower water is very popular as a flavoring material. A few drops of this latter added to ice water, sweetened with white sugar, makes a refreshing summer drink. The odor obtained from the bitter orange flowers, by the process of infusion, is much more natural and delicate than that obtained by distillation.

Patchouly.—This herb—*pogostemon patchouly*—growing extensively in India and China, affords, by distillation, a dark-brown essential oil of very powerful and peculiar odor, which is agreeable when diluted. It enters into the composition of certain bouquet scents. The dry and powdered herb is used for sachet powder, on account of its property of keeping moths out of clothes.

Pea.—The flowers of the sweet pea or chick vetch, *lathyrus odoratus*, as it is also called, eliminate, by a process of infusion, a very grateful odor.

Pink.—The clove pink flower, *dianthus caryophyllus*, gives out a delightful aroma, which may be extracted by the process of enfleurage.

Rose.—This plant, *rosa centifolia provincialis*, is largely cultivated throughout Turkey, at Ghazepore in India, and in the Southern part of France, and also at Mitcham in England, for the manufacture of *rose water*, and *otto or attar of rose*. This latter is the essential oil of the flowers; and that made at Grasse takes the precedence of attar from all other countries. The bulk of supplies, however, comes from Turkey and India. The rose water made at Provence is distinguished for its very superior quality. Both it and the attar are obtained by distilling the flowers; two thousand roses yielding little more than a drachm of the latter. The odor may also be extracted by infusion or enfleurage; and thus obtained, it is much more natural and fragrant than that made by distillation. In Asia Minor, the attar is made by distilling the rose buds, without water, by the heat of a saline bath.

The odor is very popular, but must be used in a diluted state.

A fictitious rose water, which, according to WAGNER, might be used in perfumery, is made by decomposing the volatile oil of gaultheria—salicylate of oxide of methyl—with caustic potassa, and distilling. The distillate is the required product, and possesses an odor closely resembling that of the rose. This odor characterizes the products of the spontaneous decomposition of salicylate of potassa.

It has a very general application in the several branches of the art of perfumery.

Rosemary.—This plant—*rosmarinus officinalis*—gives, on distillation, a thin essence, with a characteristic aromatic and stimulant odor. It is generally employed, in combination with other perfumes, as an ingredient of *Hungary water*, *Cologne water*, and certain Bath waters.

Sage.—The leaves of this plant—*salvia officinalis*—are sometimes used, when dried and ground, for scenting soaps; and as an ingredient for sachet powders. The odor is strong, aromatic, and fragrant.

Spike.—This perfume has already been described under the head of *Lavender*.

Syringa.—This plant—*philadelphus coronarius*—is the *mock orange* of America. Its flowers emit an intense odor, very similar to that from orange blossom; and which may be extracted by the process of infusion or enfleurage.

Thyme.—The lemon thyme—*thymus serpyllum*—yields by distillation an oil of herby, rather than flowery odor; and it is, therefore, rarely used as a perfume. The dried and ground plant is sometimes used in sachet powders. Thyme oil is generally sold as oil of organum; but the odor of the two is widely different—that of the latter, when genuine, being more like peppermint than thyme.

Tuberoze, or Tubereuse.—This is a very fleeting perfume, obtained by the process of enfleurage, from the flowers of the *polianthes tuberosa*—largely cultivated for that purpose at Grasse. Its rich and exquisite smell makes it a valuable agent in compounding the finer kinds of bouquets. A little extract of orris or vanilla must be added to impart permanence to it.

Verbena, or Vervain.—This is the scented species of the plant, *alloysia citriodora*. By distillation, it affords an odor of rare fragrance, which is seldom to be met with in commerce. The oil of lemon grass, diluted with alcohol, which is closely assimilated to it, is generally vended for it. It is used in *court bouquet*, *Portugal water*, and a number of the finer scents.

Violet.—From the flower of the *viola odorata* is obtained an odor, which, in its genuine state, is of the choicest fragrance. There are few perfumes more highly esteemed. The flowers are largely cultivated at Nice, Grasse, and also in the vicinity of Florence, where they are subjected to the process of infusion, in order to extract their delicious aroma. The essence thus obtained is of a beautiful green color, and has a perfectly natural smell. Tincture of orris root is a base imitation frequently sold for the genuine substance.

Volkameria.—This odor is supposed to be derived from the flowers of the *v. incrimis*, which grows in

India. Little is known of it, and PIÈSSÈ gives the following recipe for the composition sold under the name of *essence of volkameria*:—Esprit de violette, and esprit de tubereuse—each one part; esprit de jasmin, four fluid ounces; esprit de rose, eight fluid, and essence of musk, two fluid ounces.

Wall-Flower.—The flowers of this plant—*cheiranthus cheiri*—emit a very delightful aroma, which may be extracted by the process of infusion. It is not much used, and deserves a more general application.

4. FRUITS AND SEEDS.—The materials under this head are not all used for their perfume; indeed, the majority of them serve different, though no less important purposes.

Almond.—This perfume has been much esteemed for many ages. VIRGIL speaks of it in the following lines:—

Mark well the flowering almond in the wood;
If odorous blooms the bearing branches load,
The giebe will answer to the sylvan reign—
Great heats will follow, and large crops of grain.

The kernel of the bitter almond—*amygdalus amara*—gives, on expression, a fixed oil; and the pressed cake which remains, on being macerated in water and distilled, exhales the volatile oil of bitter almonds, which does not exist ready formed in the nut, but is generated by the reaction which takes place between two of its constituents, *emulsin* and *amygdalin*, under the circumstances just mentioned. This golden yellow oil is of a pungent agreeable odor, but is highly poisonous, and must be handled and used with caution, as it always contains more or less hydrocyanic acid. This acid, which averages eight to ten per cent., may be removed by prolonged agitation with a large quantity of milk of lime and caustic potassa, and redistilling. The pure oil is hydrioc of benzoyl, with some benzoic acid; and it owes its peculiar odor to the former of these components. By judicious use, alone or in combination, it is very serviceable; particularly for scenting pomades, soaps, shaving and cosmetic creams, and meets with general appreciation. The *essence of mirabane*, which is frequently sold as the genuine substance, is an artificial product, known chemically as nitrobenzole. Its odor, however, only approximates to that of the oil of bitter almonds; nevertheless, it is largely employed for scenting soaps. Peach-kernels, by the above process, also afford a volatile oil, which is often palmed off as the genuine oil of bitter almonds. This latter is used for flavoring, as much as for scenting. The kernels or nuts of the sweet almond—*amygdalus dulcis*—do not yield any volatile oil, unless they are mixed with bitter almonds; but they give by expression a very mild fixed oil, which is much esteemed for making cosmetic pastes, creams, and the like. It is called oil of sweet almonds.

Ben.—This plant is the *mohringa optera* and *oleifera*, indigenous to Arabia and Syria, but growing also in the West Indies. By expression a fixed oil results, which is colorless, tasteless, and inodorous. The oil, after repose, separates into two portions; one of which is thick, and the other very fluid, even at low temperatures. The obstinacy with which it retains its neutrality, and resists the rancifying action of prolonged

exposure, combined with other desirable properties, render it an admirable vehicle for the extraction of certain delicate odors. It is, therefore, much in vogue in the process of infusion and enflerage.

Bergamot.—The rind of the fruit of the *citrus bergamia* gives the well-known oil of bergamot by expression. Its odor is mild and eminently agreeable; and when mixed with other odors, greatly enriches their sweetness. The oil should be kept in tightly-stopped bottles, else its scent will become impaired.

Caraway.—The seeds of this plant—*carum carui*—yield, by distillation, the oil of caraway, much used for perfuming soaps, and particularly that kind known as *old Windsor*. It also enters into the composition of cheap essences. The seeds, in a ground state, are employed in certain sachet powders.

Cedrat.—The rind of the citron fruit—*citrus medica*—yields the oil of cedrat, both by expression and distillation. Its odor is lemon-like. This oil is expensive, and is mixed only with the finer perfumes.

Cloves.—The perfume from this plant, *caryophyllus aromaticus*, is one of the most ancient and useful. Every part of this plant contains aromatic oil, but the flower-buds are the most prolific portion. The oil may be obtained by expression, but much more economically by distillation, which is the mode generally followed. Its odor is strong and fragrant, and renders it a prominent ingredient of a very numerous variety of perfumes.

Cocoa.—The kernels of the cocoa palm, *cocos nucifera* and *butyracea*, growing in Brazil, Ceylon, and Bengal, when ground and subjected to hot-pressure, part with a white butyraceous fat, which has a disagreeable odor, of which it may be relieved by melting it with powdered benzoin, and afterwards straining. It has a limited application for common pomades, and as fat-stock for certain kinds of toilet soap.

Dill.—This plant, *anethum graveolens*, is cultivated in all the countries of Europe, and bears a strong smelling aromatic fruit or seed which, on distillation, eliminates a volatile oil, and a pleasant-smelling water, called *dill water*. This latter, mixed with rose water, is used, according to PIÈSSÈ, as a cosmetic for clearing the complexion. The oil may be employed in combination with others for scenting soaps.

Lemon.—The rind of the lemon fruit, *citrus limonum*, by expression evolves the well-known essential oil of lemons, which comes principally from Messina, and has a delightful odor. By time and exposure it becomes altered, and loses fragrance; it must, therefore, be used fresh. It enters largely into the compound perfumes and Cologne waters, but will not answer for scenting greases, as it promotes their rancidity. Like bergamot oil, it is often adulterated by the dealers with oil of turpentine.

Mace-Nutmeg.—Ground mace is sometimes to be found in sachet powders. It is the reticulated membrane investing the kernel or nutmeg of the *myristicha mosehata*. The nutmeg emits by distillation, a fine fragrant volatile oil. It also yields, by expression, a fixed oil, called oil of mace. It is concrete, yellowish, and of an agreeable aromatic odor. Its application in perfumery is very limited.

Orange.—The *essence of Portugal*, heretofore de-

scribed under *Neroli*, is obtained by expression and distillation from the rind of the sweet orange. It is a very agreeable and popular perfume, and the prominent ingredient of many fragrant waters.

Palm.—The palm fruit, *avaira clais*, on being boiled with water, sends to the surface a butyraceous orange-colored fat of a violet-like odor. It is met with chiefly in admixture with tallow to make fine palm soap, and in small quantities for coloring pomades. The odor of the oil may be extracted by infusion in alcohol.

Tonquin.—The tonka or *coumarouma* bean, is the seed of the *dipterix odorata*, a plant growing in Guiana. It emits a strong, agreeable, aromatic odor, which may be extracted by infusion in alcohol. The tincture thus made is used in small quantities in a large number of compound scents, and particularly the *bouquet du champ*, on account of its assimilating in odor to new hay. The bean itself, when ground, forms an ingredient of many sachet powders.

Vanilla.—The pod or bean of the *vanilla planifolia* or *aromatica*, a plant of the West Indies, Mexico, and South America, emits a very fragrant and peculiar odor, which may be extracted in the form of tincture, by infusion in alcohol. It enters largely into the composition of bouquet odors, hair washes, *et cetera*, and is also a favorite material for flavoring confectionary.

5. BALSAMS AND RESINS.—The balsams used in perfumery are, the *Peru balsam*, from the myroxylon peruiferum; *tolu balsam*, from the myroxylon toluiiferum; *balm of gilead* or *mecca balsam*, from the amyris opobalsanum; *labdanum*, from the cistus creticus; *storax*, from the liquidamber styraciflua; *benzoin*, from the styrax benzoin; and *myrrh*, from the balsamodendron myrrha. Some are in the form of fluid resins, while others are concrete, as labdanum, myrrh, and benzoin. All are exudations from plants, flowing out naturally, or else produced by incisions. Most of them are of oriental origin, and the supplies of all come from abroad. Their odors are aromatic and agreeable, that of labdanum being amber-like. Myrrh has a peculiar fragrance, and is more used for odontalgic preparations than as a perfume. This class of substances impart their aroma to alcohol in the form of tincture, and in that state are valuable adjuncts to the perfumer. They constitute the *foundation* or less volatile portions of many compound odors, and give consistency to the scent, and fix those ingredients which are more delicate and fleeting. They must be used judiciously, and in small quantities, as directed for the odors of musk, vanilla, and the like. Benzoin is also employed in a powdered state, as an ingredient of certain sachet powders.

The subject of BALSAMS is fully considered in Vol. I., pages 222–35, of this Dictionary. There are two other materials, neither of which belong properly to any of the classes enumerated, and as one of them is of prime importance in the art of the perfumer, they are entitled to an independent paragraph.

ALCOHOL AND CARAMEL.—*Alcohol*.—The manufacture and rectification of alcohol have already been described in Vol. I., pages 48–149. The Editor will only remark, that for the purposes of perfumery it should be wholly free from the odor of fousel oil, which is

peculiar to rye and corn spirit. In that respect, the French grape spirit is peculiarly adapted for the delicate perfumes, as it has rather a grateful aroma itself, which assimilates well with that of the scent substances. The grain spirit, on the contrary, is preferable as a solvent for the strong odors. HYDE proposes to remove fousel oil and analogous matters, by distilling the alcohol—eighty-five to ninety per cent.—with half a per cent. of manganate of potassa or soda, dissolved in a small quantity of water. The valerianic and other acids thus generated from the fousel and associate oils, combine with the alkali of the manganic salt, and remain fixed, while the alcohol passes over, pure and inodorous.

Caramel.—This useful coloring matter is made by heating brown sugar to 400°–430°, dissolving the product in water, and precipitating with alcohol. The blackish brown deposit is pure caramel, readily soluble in water; and it may be separated from the liquid by straining. A commoner article is the heated sugar merely dissolved in water and strained, the subsequent precipitation being omitted.

MINERAL SUBSTANCES.—This class comprises only a few materials, which are used rather as *body* or coloring matters. *Subnitrate of bismuth* is the *pearl white* for the complexion. A less objectionable preparation would be a mixture of *native sulphate of baryta* and *prepared chalk*—precipitated carbonate of lime. These latter two, while being as white as the former, are not, like it, discolored by the sulphur fumes in the atmosphere, nor so particularly injurious to the skin.

Mineral Tale.—A smooth, greenish-white earth, forms the *body* of tinted rouges. The different colored ochres are also sometimes used as pigments for soaps.

EXTRACTION OF SIMPLE ODORS.—*By Distillation*.—This process is necessary for the preparation of nearly all the essential or volatile oils, the fragrant waters, and more particularly Cologne waters. The apparatus consists of a metallic still and its appliances, for general purposes; but in certain cases, such as the distillation of vinegars and other substances that might act upon metal, glass or stoneware retorts are the proper implements. These latter, it should also be remembered, are better applicable for small and nice operations.

Essential Oils.—These so-called oils are misnomers, as they have none of the chemical or physical properties of true oils. They should be more properly designated by the title of *attars*. They differ from the fat or fixed oils in not being saponifiable, or greasy to the touch. They are, moreover, volatile; and being the odorous principle of the plants, each is consequently characterized by a scent. In specific gravity they range from 0.759—attar of coriander—to 1.094—attar of saffras. They have, generally, an acid burning taste, and while many are colorless, some are yellow, red, or brown, others green, and a few blue. They burn with a brilliant flame and much smoke, and by prolonged exposure become thick and resinified. In ultimate composition they are chiefly hydrocarbons; but some few contain oxygen, and a certain class sulphur as a constituent. Their proximate components are *elaopten* and *stearopten*, the former of which is more fluid than the latter,

and may be separated by pressure when the oil is congealed.

The purity of essential oils is all-important, as they are used solely for their perfume. Those found in commerce do not always have that quality, but are frequently debased with alcohol, spirit of turpentine, resin, balsam copaiva, or some oil of inferior price. The detection of the latter fraud is very difficult—in most cases the specific gravity being the only test. The presence of resin or balsam is elicited when a drop of the suspected oil, heated upon a piece of paper, leaves a greasy spot.

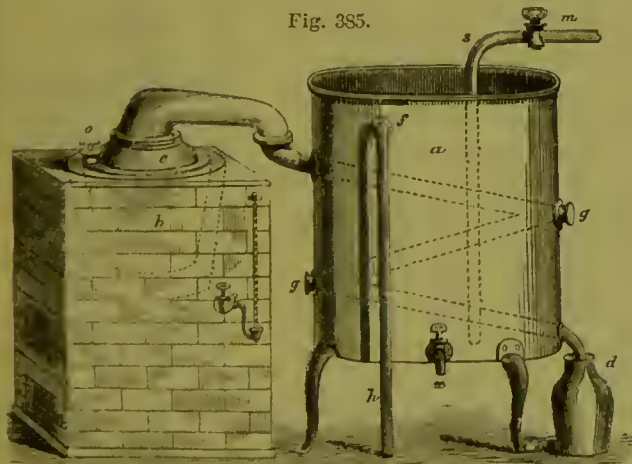
Alcohol is to be tested for, by placing a lump of perfectly dry chloride of calcium in a test-tube containing the suspected oil, and shaking it well. If the attar is pure, the chloride of calcium will remain unaltered; but if it contains alcohol, the lump will dissolve and form a dense substratum.

Spirit of turpentine is often used to cheapen the strong-scented attars, such for example as the attar of lavender. MERO has proposed an excellent method for its detection. It consists in placing one drachm of the attar with an equal volume of oil of poppy in a test-tube, and heating them in a water bath. If the attar does not contain spirit of turpentine, the mixture remains turbid; but if, on the contrary, it be present, the poppy oil is dissolved, and the menstruum becomes clear.

Attar of roses is often mixed with attar of geranium; but the presence of this latter may be ascertained by means of nitric acid, which imparts an apple-green hue to the latter, while it tinges the rose dark yellow.

The still used for the oils should be constructed so as to serve for all the distilling operations of the laboratory, and must, therefore, be set for use either with the naked fire or steam heat, as may be desired. MORFIT, in his *Chemical Manipulations*, describes an excellent arrangement, the whole of which is shown in front view by Fig. 385, just as it appears when in operation. The brickwork in which it is set abuts

Fig. 385.



against the chimney and connects with the flue, through the furnace of the still. This furnace, instead of being in front to inconvenience the operator with its heat and dust, is placed at the side, the lower door being the entrance to the ash-pit, and the upper to the furnace or fire-hole. The refrigerant or cooling-tub, *a*, has its position to the right of the brickwork.

The lower portion or body of the still, *b*, is made of heavy sheet-copper tinned interiorly. The head, *c*, is cast wholly from pure block-tin. Projecting from the inside of the still, near the bottom, is a tinned copper tube *d*, which passes forward through the brickwork and ends in a stopcock fixture, from which rises a glass tube *e*. The tap serves to shut off communication between the still and tube, as may be necessary in case of accident to the latter; and the tube itself, graduated into inches, presents a scale which will at all times indicate the height of the liquid. This indicator is protected by a half-casing of metal, in which it rests against the front wall of the brickwork, a clamp or two serving to keep it steady. There are two supplementary parts in the still, one of which is a colandered lining of block-tin, shown by Fig. 386, and the other by Fig. 387, a perforated false bottom of the same material. The first is made to fit to the mouth of the still in such a manner that the same head will adjust with both the inner and outer vessel equally well. The latter is intended as a support for organic or other matters alterable by contact with highly-heated surfaces, and is more particularly adapted for distillations with the naked fire. As it may be necessary frequently to remove this bottom, for the purpose of cleansing it, or dispensing with its use in some operations, it is constructed of two parts, connected by hinges in the centre, so as to form a fold which will pass through the mouth of the still.

Fig. 386.



Fig. 387.



The block tin colander, exhibited in the drawing of the still by dotted lines, is designed for use in the distillation of bulky substances, particularly those of vegetal origin, by a direct current of moist steam. It allows, in a degree, the application of the displacement principle in distillation; for, as the current of steam enters, it passes upwards through the holes, thence through the mass of matter supported in the colander, and the first portion of the distillate reaches the condenser saturated with the volatile parts of the substance under treatment, and without mixture of any light, solid particles driven over mechanically, as would otherwise be the case. The process effects filtration at the same time that it constantly renews the surface of the solid matter to the solvent action of succeeding relays of fresh steam, while it also affords the means of determining when the former is exhausted, and the distillation should be stopped.

The steam-pipe is introduced through the opening, *o*—Fig. 385—and leads to within an inch of the bottom, where it takes an angular bend, and ends in a rose, which is a perforated copper ball, with a screw-cut shoulder, by which it is attached to the steam-pipe. The latter is so adjusted in the opening, by means of a shoulder and coupling-nut, as to form a tight joint. When the still is to be used with the naked fire *alone*, this pipe must be removed, and the opening closed with a screw-plug provided for the purpose. It should be remarked that this opening serves also for the entrance of a funnel—

tube through which to introduce fresh additions of liquid as may be required, to maintain a supply in the still, without the necessity of stopping the operation or removing the head.

The distillate, in passing from the still-head, goes into a worm, *gg*, firmly fixed in the cooler, *a*. The worm is a series of block-tin tubes, as shown by the dotted lines. The mouth of the first joint receives the beak of the still-head, and that of the last joint empties, through a bent nozzle, into the receiving-vessel, generally a glass or stone jar, as seen at *d*. To facilitate the cleansing of the joints, they are fitted at the ends, *g*, with screw-plugs, which being removed, allow free access to the interior with a cloth and ramrod.

The cooler is made of galvanized iron, or, still better, of tinned copper; and in order to accommodate the long joints of the worm which is soldered to it, its form is oval. The pipe through which it receives cold water is close to the side, and extends nearly to the bottom, as shown at *s*. A connection with the hydrant is made by a branch-pipe and tap, as shown at *m*. The opening for the exit of the warm water is seen at *f*, and leads into another pipe, *h*, running down the outside of the cooler into the drain or gutter. A tap, *x*, serves for draining off sediment, as it accumulates by deposition from the water.

When it may be desired to use dry steam, then the block tin colander, Fig. 386, must be replaced by one which is close and not perforated. There will then have to be an opening and tube opposite to *o*, for carrying away excessive steam. The jacket thus formed

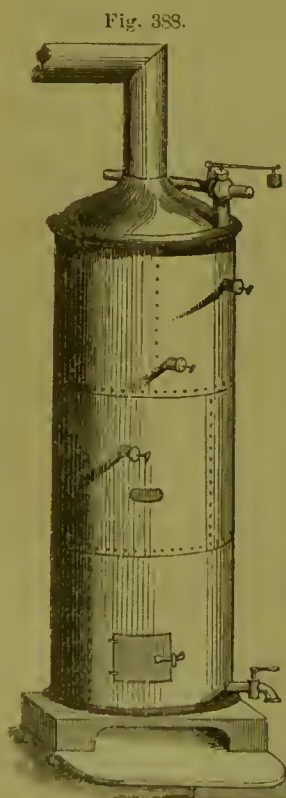


Fig. 388.

gives the convenience of using it also as a water or saline bath, when operating with fire direct, instead of steam. The water or saline solution is, of course, placed in the outer case or body of the still proper, *b*, and thus surrounds the inner vessel, containing the matter to be distilled. Steam may be supplied from a small portable generator, such as are now made for purposes of this kind, and here shown by Fig. 388. Great care is requisite in cleaning the several parts of the still arrangement at every change of operation.

In the distillation of roots, woods, barks, flowers, seeds, *et cetera*, the best heating medium is steam, as it allows a better regulation of tem-

perature than can be accomplished in the use of the naked fire. Moreover, it removes all liability of scorching the materials. A current of steam passing from the generator under a pressure of fifty pounds to the square inch, has a temperature of 280°, which

is much higher than is needed for any material under present consideration.

The part of the plant yielding the odor, after having been bruised or cut into small pieces, is to be placed in the colandered vessel, or on the perforated bottom, with as much water only as is necessary to drench the material; and when the oil to be obtained is heavier than water, the density of the latter must be increased by nearly saturating it with table salt, which also raises its boiling point from 212° to 220°. The head of the still—Fig. 385—is then put in place, and the joints closed. Steam is next let on through the pipe, *o*, and the current continued until oily distillate ceases to come over.

If the quantity of water is too much in proportion to the amount of material to be distilled, then a portion of the oil remains dissolved therein, and does not separate. The same result occurs when the oily constituent is in limited quantity. In all such cases cohobation is necessary. That is, the distillate or liquor first passing over must be poured back repeatedly, upon the same or fresh material, and as often redistilled. Indeed, in all distillations where fresh relays of water are used, the last running, which is of feeble strength, should be reserved as the first water for the next operation with fresh material. In this way the small portion of oil which it may have contained is economized. As the volatilization of the water is coincident with that of the oil, the two must be received together, as they condense, in a vessel which will admit of the ready separation of them by reason of their different specific gravities. Fig. 389 represents the Florentine receiver, which is used for the lighter oils. The oil, accumulating at *a b*, retains its supernatant position throughout the distillation, while the water beneath flows out at *c*, as fast as it runs from the still. When the oil is denser than the water, a different arrangement, as shown at Fig. 390, is required. The denser oil is drawn off, by opening the tap of the barrel, as fast as it separates and subsides from the lighter water.

It is very necessary that the water in the refrigerant should be replaced by cold water as fast as it becomes warm; except for those oils, such as anise and rose, which thicken readily. The temperature of the water must be regulated in accordance with that property.

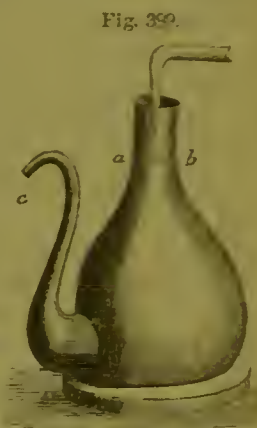


Fig. 389.



Fig. 390.

Scented Waters.—All substances which yield essential oils, give at the same time a scented water of superior excellence; for example, *orange flower water*; and the difference in the density of the two products permits their separation in the manner just described. There are some materials, again, which are too feeble in odor to give an attar, and may yet be made to impart their scent to water. In either of those cases, and also when it may be desired to obtain only a water from those substances which would yield an essential oil, the quantity of water employed must be much larger than for the oil distillations. And for the reason, that now the object is to obtain solution of *all* the essential oil in *water*, and not to promote the separation of the two, as before directed.

The process and manipulations are the same as just described for distilling the essential oils, except that only the first three-fourths of the distillate are preserved. A little rectified spirit may be advantageously added, before setting aside the scented water for preservation. Wet steam is by far the preferable means of heating. The flowers should be as fresh as possible, and free from stems. *Double distilled rose water* is made by distilling over two gallons from a mixture of twelve pounds rose leaves, and two and a half gallons water. In the same way, nine pounds of elder flowers and four gallons of water give three gallons of *elder flower water*.

By Expression.—This method is adapted only for those substances which are very rich in essential oil; as examples, the rinds of the lemon, orange, citron, and some other fruits. The chief implement is a powerful press. The material is either inclosed in hair bags, or

a tinned metal box—Fig. 391—resting upon the bottom of the press. The box must be lined with a perforated cylinder—Fig. 392—having perpendicular ribs on the exterior circumference. These latter, projecting against the inner sides of the box, form channels by which the flow of the expressed oil is facilitated, and its free passage into the receiving vessel maintained. Being in two parts, connected by a hinge and movable pin, it can be conveniently emptied and refilled, as becomes necessary. The follower—Fig. 393—being directed forcibly downwards upon the contents of the box by the mechanism of the press, crushes



Fig. 391.



Fig. 392.



Fig. 393.

the oil vesicles, and drives out the oil, and along with it some water and mucilage, and foreign matters, which may be separated by sufficient repose and straining.

By Infusion or Maceration.—This process is mostly used for those substances, the odor of which is too delicate for distillation, such as the flowers of the cassie, bitter orange, and violet; and sometimes also the rose and the like, the natural perfumes of which it is desired to obtain in the maximum state of perfection.

The infusion medium is a mixture of beef or mutton

suet, and lard, refined in the manner already directed. The necessary apparatus is one of the steam pans heretofore referred to, but it must be tinned or enamelled interiorly, and fitted with a tight cover. The fat body having been melted, the flowers or odoriferous material are wholly immersed in it, and left for a day, care being taken to stir the mixture occasionally with a wooden stick. In this time the flowers have become exhausted of their perfume by the fat, and must, therefore, be separated by remelting, straining through a fine hair-cloth sieve, and pressing the marc. The spent flowers are then replaced by a fresh charge; and so these renewals are continued until the fat has sufficient odor. In this way various strengths may be obtained, and are generally designated by numbers, according to the number of infusions which the fat has undergone. After the last straining and pressing, the expressed matter should be allowed sufficient repose to clean itself. The darker substratum which thus deposits may then be removed from the clear upper portion, and sold as an inferior quality.

In this manner the finer sorts of French pomade are prepared. Sometimes oil of ben takes the place of suet as the infusion medium, and then the products have the name of *huile antique*.

By Enfleurage.—There are certain flowers, the odors of which are so delicate that they will not bear even the little heat used in the preceding method; and for these the process of enfleurage or absorption is employed. Jessamine, mignonette, tuberose, and similar flowers, belong to this category.

HANBURY thus describes the operation as conducted at Grasse and Cannes. The apparatus required is merely a number of shallow wooden frames of about eighteen by fifteen inches, inclosing at half their depth a sheet of glass. The edges of the frame rise about an inch above each surface of the glass, and, being flat, the frames stand securely upon one another, forming often considerable stacks. The technical name for the frames is *chassis*; those just described are called *chassis aux vitres*, or *chassis aux pommades*, to distinguish them from a different form, which is used where oil has to be submitted to the process of enfleurage. The process in the case of pomade is thus conducted: the unscented fat is weighed into portions, each sufficient for one side of the sheet of glass of a *chassis*. It is then spread over the glass with a spatula in a layer hardly a tenth of an inch thick, care being taken, by employing a little inner frame during the spreading, that the fat does not come in contact with the wood-work of the *chassis*. One surface of the glass having been thus coated, the other is covered in like manner, and the *chassis* is ready to receive the flowers. These are now thinly sprinkled, or rather laid, one by one, upon the surface of the fat, where they are allowed to remain until the next day or day after, when they are dexterously removed with nippers, so as not to soil the fat, and fresh flowers supplied. The *chassis*, charged with fat and flowers, are stacked one upon the other, forming, in fact, a number of little rectangular chambers, the upper and lower surfaces of each of which are of glass, covered with a thin layer of fat sprinkled with flowers, the sides being of wood. In one manufactory

which the Editor inspected, only one surface of each *chassis* was coated with fat, the jessamine flowers being placed in an abundant layer upon the other surface. In another establishment the flowers of mignonette were being similarly treated. In this arrangement the flowers do not, of course, come in contact with the fat, but the latter is simply suspended above them to receive and absorb their odor. The flowers require changing, either daily, or every other day, for a month or two, before the pomade is sufficiently impregnated with their odor. It is of paramount importance that all flowers employed in this process should be collected during warm weather.

After the last impregnation, and when the fat is sufficiently fragrant, the pomade is removed with a spatula, and put into close cans.

By Alcoholic Solution.—The extraction of odors by means of alcohol from scented fats, will be more fully explained under the head of *Extraits*. The Editor will here limit himself to the description of essences and tinctures.

ESSENCES.—These, in the language of perfumery, are nothing more than solutions of essential oils in deodorized alcohol. The proportion of oil varies from two drachms to two ounces, and the manipulation consists in merely mixing and shaking the two together. Sometimes they are subsequently distilled with a little water, and then they are called *distilled aromatic spirits*. Cologne, lavender, and similar waters are thus made. For example, SMYTH makes his famous *essence of lavender* by mixing together—English attar of lavender, four ounces; deodorized alcohol of ninety-five per cent., five pints; rose water, a pint; and distilling off, five pints.

As examples of essences by simple mixture may be named—

	Essential Oil.	Deodorized Alcohol of 95 per cent.
Essence of lemon,.....	one fluid ounce.	a quart.
“ bergamot,.....	—	a quart.
“ rose—triple,...	one ounce and a half.	two quarts.
“ thyme,.....	two drachms.	two quarts.

Tinctures.—When both of the substances are fluid, as in the case of certain balsams, then the spiritous solution is made by merely mixing the two together as before, in suitable proportions. For instance—

	Tolu balsam.	Alcohol.
Tincture or essence of tolu,...	three drachms.	a quart.

There are, however, many solid substances which are treated with alcohol, for the extraction of either their odor or coloring matter. These menstrua may

		Troy.	Alcohol.
Tincture or essence of vanilla,.....	vanilla bean—rasped,.....	eight ounces,.....	eight pints.
“ “ musk,.....	grain musk,.....	two drachms,.....	eight pints.
“ “ frangipani,.....	powder a la frangipani,.....	one pound,.....	six pints.
“ “ rhodium,.....	rhodium wood—rasped,.....	one pound,.....	two quarts.
“ “ civet,.....	civet, orris root,.....	half an ounce,.....	two quarts.
“ “ tonquin,.....	tonka bean,.....	one pound,.....	eight pints.
“ “ orris,.....	orris root,.....	seven pints,.....	eight pints.
“ “ alkanet—red color,...	alkanet,.....	half an ounce,.....	a quart.
“ “ turmeric—yellow,...	turmeric,.....	half an ounce,.....	a quart.

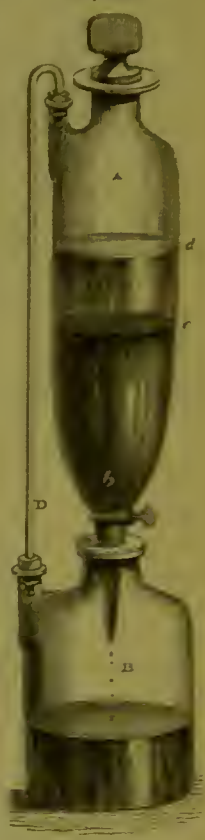
POMADES.—The *fine*, and *extra fine* or *double* pomades are made by the processes of maceration and enflourage, which have been already described at page 671. The

be made by merely macerating the substance in alcohol for ten days, and filtering off the clear tincture; but the shorter and more efficient, as well as economical method, is that known as *displacement*. To explain the operation intelligibly, let one suppose that benzoin is under treatment. The apparatus, made wholly of glass, having been arranged as shown by Fig. 394, and a plug of raw cotton dropped loosely at *b*, the benzoin in coarse powder is then poured into the tube portion, *A*, until it reaches the line *c*. Alcohol, of 66° Twaddell, is next added, until it rises to the line *d*. As soon as the first portion sinks into the benzoin, a fresh addition must be made; and thus the succeeding relays go on displacing those which preceded them, without mingling with them. Each stratum becomes more and more charged with soluble matter as it descends; and when it reaches the bottom of the mass, under the pressure of the superincumbent liquor, it runs out saturated. When, by successive additions of fresh alcohol, the benzoin has become exhausted, the liquid passes through the mass, and falls into the receiver, *B*, as tasteless and colorless as when first poured in. This indicates the completion of the process.

As atmospheric pressure is an important element in the operation, it will not answer to shut it off by closing the top of the displacer, without making some compensating arrangement; and, therefore, a communication between the upper and lower vessels is established by means of a latent-tube arrangement, *D*. In this manner the apparatus is kept close, and the evaporation of alcohol prevented, while the pressure produced is distributed throughout the vessel, and thus rendered uniform. As the runnings are clear, filtration is rarely necessary. The quantity of alcohol thus consumed need not be more than sufficient to exhaust the material; and the resulting tincture must therefore be diluted to the proper strength. Deodorised alcohol must be always used.

The following are the proportions employed for the most important tinctures or essences:—

Fig. 394.



body must be of fat purified as previously directed. Almond paste, peeled and bruised almonds, may also be scented in the same manner here directed for fats.

Pomade à l'Acacia.—Cassie leaves, fifteen pounds; body, fifty pounds, consisting of thirty-five pounds lard body, and fifteen pounds of mixed beef and mutton suets. The infusion must be repeated ten times, and each time with a fresh quantity of fifteen pounds of flowers.

Pomade à la Rose.—One pound of body and twelve infusions, and each time with one pound of fresh rose leaves.

Pomade à la Fleur d'Oranger.—Equal parts of flowers and body. Eight infusions give the required strength.

Pomade à la Vanille.—One pound of vanilla in shreds, and twelve pounds body. Infuse for twelve days; remelt, and infuse for ten days longer; melt again, and strain through a fine sieve.

Pomade à la Tubéreuse.—The enfleurage must be repeated with fresh tuberose flowers, six or more consecutive times.

Pomade aux Jasmin.—The jessamine flowers must be renewed ten times.

Pomade à la Jonquille.—The jonquil flowers need only five or six renewals.

Pomade à la Jacinthe.—The hyacinth flowers require to be renewed eight or ten times for a highly-scented pomade.

COMPOUND OR BOUQUET POMADES.—These are made by a judicious mixture of the single pomades, of which the preceding are some examples.

Pomade aux Fleurs d'Italie.—Pomades à l'acacia, à la tubéreuse, à la jacinthe, à la jonquille, each one pound. Pomades à la fleur d'oranger and au jasmin, each two pounds. Pomades au reseda and à la rose, each eight ounces. Melt together over a water-bath, color as may be desired, and strengthen the perfume with a mixture of tincture of musk, six drachms; tincture of amber, three drachms; essence of bergamot, three drachms; and essence of cloves, one ounce.

Pomade à la Frangipani.—Plain body, and pomade aux jasmin, each four pounds. Pomades à la fleur d'oranger, two pounds. Pomades à l'acacia and à la rose, each one pound. Melt together over a water-bath, and as the mass begins to cool, stir in a mixture of tincture of vanilla, four ounces; balsam of peru, one ounce; essence of bergamot, two ounces; essence of cloves, half an ounce; and tinctures of amber and musk, each four ounces. Color brown.

The name FRANGIPANI belongs to a very ancient and illustrious Roman family, and certain popular preparations are so called in honor of the grandson of MUTIO FRANGIPANI, one of its scions, who originated many agreeable combinations of perfumes during the time of LOUIS XIII. of France.

The perfume called after the above, as found in commerce, is a compounded scent, and not, as supposed, a simple extract of the *plumeria alba*, a fragrant plant of Antigua, originally named the FRANGIPANI shrub, after its discoverer.

Pomade Impériale.—Pomades à l'acacia, à la jonquille, au lilas, au réseda, à la tubéreuse, each eight ounces; pomade au jasmin, four pounds; pomade à la fleur d'oranger, one pound. Melt together over a water bath, taking care to add the pomade au lilas and

pomade au jasmin last. When nearly cool, stir in a mixture of essence of bergamot, and tincture of vanilla, each one ounce; tinctures of musk, amber, and fenugree, each two drachms; color green.

The common grade of pomades are composed of the unscented body used for preparing fine pomades, which is extemporaneously perfumed by merely stirring in the essential oils, singly or in *bouquet*, according to the odor it is desired to impart. Beef marrow, or bears' grease, are scented in this manner. White wax is to be added for *stick pomatum*.

Pomade à la Graissé d'Ours.—Bears' grease, purified, six pounds; pomade à la rose, one pound; melted together, and perfumed with essence of rose, one ounce; tincture of vanilla, one ounce.

Pomade de Moelle Bœuf.—Purified beef marrow, eight pounds. Melt, and perfume with tinctures of musk and benzoin, each two drachms; essence of portugal, one ounce; essential oil of lavender, two ounces; extract of jasmin, one ounce; and attar of roses, half an ounce. Color with a portion of unscented body, in which fresh walnut leaves have been infused.

ANTIQUE OILS.—These oils are prepared as already directed for the process of maceration and enfleurage; and they correspond with the pomades, except that olive or ben oil is used for the body instead of solid fat.

Huile Antique de la Rose de Provens.—Oil and rose leaves, each one pound. Infuse seven times, with as many relays of fresh flowers.

Huile Antique au Chevre-feuille.—Honeysuckle flowers and oil. Infuse eight to ten times, with as many relays of fresh flowers.

COMPOUND OILS.—These are judicious mixtures of the single oils. One example will suffice.

Huile Antique de Millefleurs; ou, de Bouquet Composée.—Oils au jasmin, à la rose, each eight ounces; oils à l'acacia, à la fleur d'oranger, à la tubéreuse, each four ounces; oils à la jonquille, à la jacinthe, à la vanille, each two ounces. Mix together.

The inferior qualities of the above oils are made from olive oil alone, or mixed with lard oil, scented, extemporaneously, with essential oils; for example:—

Huile à la Bergamot.—Essence of bergamot, two ounces; added to one pound of olive oil.

Huile de Néroli.—Essential oil of neroli, four ounces; and olive oil, one pound.

SINGLE EXTRACTS OR EXTRAITS.—These preparations are made by treating with alcohol the highly-scented pomades, or antique oils, obtained by the processes of maceration or enfleurage. In this way the aroma absorbed from the flowers by the fat is dissolved out. These spiritous infusions are of much more delicate odor than the so-called *essences* or *solutions* of volatile oil in alcohol. Indeed, they represent in themselves the primitive odor, in liquid form, of those plants which do not yield any volatile oil.

The scented pomade is placed in a stone vessel, and one pint of deodorized spirit added to every pound of pomade. The whole is then heated for three days over a water bath, and frequently stirred in the interval; after which the alcoholic liquor is drawn off from the fat, and put through the same operation repeatedly, with fresh quantities of pomade, until it has acquired sufficient

strength of odor. A revolving churn may be substituted for the digesters and water bath; and this arrangement has the advantage of eliminating the perfume in a state of great integrity, there being no heat used. The churn may be barrel-form, and placed horizontally, so as to facilitate the turning of the crank which imparts motion to the dash-paddle in the interior.

The liquors thus obtained are simple extracts of the most superior quality and natural odor, and form the bases of the compound extracts or *bouquets* so popular as perfumes for the handkerchief.

The pomade or oil, after treatment, still retains some odor, and is, therefore, valuable material for the stick and common pomades, or as fat stock for new treatment with fresh flowers.

Extrait de jasmin, Extrait de violette, Extrait de tubéreuse, are examples of preparations made according to the preceding directions.

COMPOUND EXTRACTS OR BOUQUETS.—*Extrait de bouquet*.—Extraits de jasmin et violette, each two pints; extraits d'acacia, rose, œillet, et des fleurs d'oranger, each one pint; flowers of benzoin, two drachms; tincture of amber, four ounces. Mix and filter.

Bouquet d'Amour.—Extraits de rose, jasmin, violette, acacia, each one pint; tinctures of musk and ambergris, each half a pint. Mix and filter.

Jockey-club Bouquet.—Extraits de rose et tubéreuse, each one pint; extrait de cassie, half a pint; extrait de jasmin, four ounces; tincture of civet, three ounces. Mix and filter.

Bouquet des Millefleurs.—Extrait de rose, one pint; extraits des tubéreuse, jasmin, fleur d'oranger, cassie, et violette, each half a pint; essence of cedar, four ounces; tincture of vanilla, ambergris, and musk, each two ounces; essence of rose, half a pint; attar of bergamot, one ounce; attars of almonds, neroli, and cloves, each ten drops. Mix, leave to repose for a week, and filter.

Bouquet de la Reine.—Extraits de rose et violette, each one pint; extrait de tubéreuse, half a pint; extrait de fleur d'oranger, four ounces; attar of bergamot, two drachms. Mix and filter after a week's repose.

Bouquet Royal.—Extrait de rose, one pint; extraits des jasmin et violette, each eight ounces; extraits d'acacia et verveine, each two and a half ounces; essence of rose, half a pint; attars of lemons and bergamot, each two drachms; tinctures of musk and ambergris, each one ounce. Mix, and after eight or ten days' repose, filter.

Bouquet of Spring Flowers.—Extraits de rose et violette, each one pint; extrait d'acacia and essence of rose, each two and a half ounces; attar of bergamot, two drachms; tincture of ambergris, one ounce. Mix, and after ten days, filter.

There are certain *bouquets*, of fine odor, which may be compounded direct from the volatile oils; as an example, there is—

Bouquet de Rondeletia.—Attar of lavender, two ounces; attars of cloves and bergamot, each one ounce; attar of roses, three drachms; tinctures of musk, vanilla, and ambergris, each four ounces; deodorized alcohol, one gallon. Mix, and after a month's repose, filter.

COLOGNE AND OTHER FRAGRANT WATERS.—These preparations are mostly solutions of *bouquets* of essential oils, or extracts, in alcohol, improved by distillation. For common kinds distillation is omitted.

Eau de Cologne—Dorocherau's.—Inodorous alcohol, one gallon; attars of portugal and bergamot, nine drachms; attar of neroli, ten drachms; attar of petit-grain, twelve drachms; attars of lemon, lavender, and rosemary, each one ounce; rose, jasmin, and orange-flower waters, each two ounces. Mix by shaking, and after two weeks' repose distil, and set aside for a year.

Eau de Cologne—Double.—Inodorous alcohol, three gallons; attar of bergamot, twelve ounces; attars of cedrant, lemon, and portugal, each two ounces; attar of lavender, one ounce; attars of neroli and rosemary, each two and a half ounces; attar of thyme, one drachm. Mix, and after a week's repose, distil, and then dilute with orange-flower water until the liquor marks.

Eau de Cologne.—Spirit from grape, sixty over proof, six gallons; attar of neroli petale, three ounces; attar of biggasade, one ounce; attar of rosemary, two ounces; attar of orange peel, five ounces; of citron peel, five ounces; and of bergamot peel, two ounces. Mix with agitation, then allow it to stand for a few days undisturbed, filter and bottle.

Eau de Rondeletia.—French alcohol, one gallon; attar of lavender, two ounces; attars of cloves and bergamot, each one ounce; attar of roses, three drachms; tinctures of musk, vanilla, and ambergris, each four ounces. Mix, and leave to repose for a month, then filter and bottle.

COSMETICS.—The preparations under this head are designed to soften the skin and beautify the complexion. We annex recipes for the more important. The heating medium in the manufacture of them must be either a water or steam bath.

Amandine.—Put into a large marble mortar two ounces gum arabic, and six ounces white honey, triturate, and when the mixture has been rubbed into a thick paste, add three ounces perfectly neutral almond shaving paste. Then continue the trituration until the mixture has become homogeneous. Two pounds of fresh cold-pressed sweet almond oil are next allowed to flow from a can above into the water, but only as rapidly as the workman can incorporate it with the mass; otherwise, if it enters in too large quantities, the blending is imperfect, and the amandine becomes *oily* instead of jelly-like and transparent, as it should be when the manipulation has been skilful. In summer temperatures it will be difficult to effect a combination of all the oil; and, therefore, the flow should be stopped as soon as the mixture becomes bright and assumes a crystalline lustre. The perfume should be mixed with the almond oil, and consists of half a drachm of attar of bitter almonds to every pound of paste. A little attar of rose and bergamot may also be added—about one drachm of each. As soon as finished it must be put in close pots. A small quantity, say a lump of filbert size, gives with warm water a rich lather, which, when rubbed over the face and hands, imparts softness, and prevents chapping. It should be wiped off, while still in lather, with a dry towel.

Camphor Ice.—Melt together over a water-bath, white wax and spermaceti, each one ounce; camphor, two ounces; in sweet almond oil, one pound. Next, triturate in the manner directed for amandine, and allow one pound of rose water to flow in slowly during the operation. Then perfume with attar of rosemary, one drachm.

Crème de Cathay—Farina.—Melt together over a water-bath white wax and spermaceti, each two drachms; then add oil of sweet almonds, four ounces; and mecca balsam, three drachms; next, perfume with rose water, six drachms; and stir until cold.

Glycerin Cream.—This superior cosmetic is the well-known *cold cream*, with glycerin substituted for rose water. Melt together spermaceti, six ounces; and white wax, one ounce; in one pound of sweet almond oil. Then remove from the fire, and stir in PRICE'S glycerin, four ounces; and when congealing, perfume with attar of rose, twenty drops. Other attars may be used as desired in place of rose.

Pâte d'Amande au Miel.—Rub together one pound of honey and the yolks of eight eggs; then gradually add sweet almond oil, one pound, during constant trituration; and work in bitter almonds—blanched and ground to meal—eight ounces; finally perfume with attars of bergamot and cloves, each two drachms.

Pomade Rosat—for the lips.—Melt together white wax, two ounces; oil of sweet almonds, four ounces; alkanet, three drachms. Digest for several hours, strain, and add twelve drops of attar of rose.

Crème de Psyché—for the lips.—White wax and spermaceti, each one ounce; oil of sweet almonds, five ounces. Melt together, and pour in mecca balsam, one drachm, and stir until the mass congeals, when add ten grains of powdered acetate of lead.

Lait Virginal.—Orange-flower water, eight ounces; and tincture of benzoin, two drachms. The former is added very slowly to the latter during constant trituration, so as to produce an opalescent milky fluid.

Milk of Roses.—Place over a water-bath, oil soap one ounce; and melt it in five or six ounces of rose-water; then add white wax and spermaceti, one ounce; and continue the heat until they have fused. Next take one pound of blanched almonds, beat them to meal in a clean marble mortar, with three and a half pints of rose-water, admitted portionwise, during the trituration. The emulsion of almonds, thus made, is to be strained without pressure through washed white muslin, and run very slowly into the previously-formed soap-mixture; the whole being blended at the same time by energetic trituration. Towards the end of this operation, two drachms of attar of rose, dissolved in eight ounces inodorous alcohol, is to be let into the mixture very gradually, and in a thin stream, during constant rubbing of the mass. This cautious manipulation is indispensable to the smoothness and perfection of the milk. The last operation is to strain; and after the liquid has had a day's repose, to bottle it.

Piessè's Milk of Cucumber.—Heat two pints juice of cucumbers to boiling, cool and strain; and make into milk, as above directed, with sweet almonds, four ounces; green oil and wax, and curd soap, each half an ounce; alcohol, eight ounces, and essence of cucumber,

four ounces. This latter is made by digesting twenty-eight pounds bruised cucumbers with two pints of alcohol of .837 specific gravity for twenty-four hours; and then distilling off one pint and a half.

Crème de Pistache.—Pistachio nuts, three ounces; green oil, palm soap, wax, and spermaceti, each one ounce; orange-flower water, three and a quarter pints; essence of neroli, twelve ounces; make as directed for the preceding milks.

PREPARATIONS FOR THE HAIR.—In addition to the various kinds of pomades and antique oils already described, there are other special preparations used for promoting the growth, health, and beauty of the hair. Annexed are formulæ for those most esteemed.

Philocome.—This compound is made without heat. Equal parts of purified beef-marrow, oils of noisettes and sweet almonds are thoroughly mixed by trituration in an agate or marble mortar; and the whole is then perfumed by the addition of a sufficient quantity of a mixture of extracts of rose, acacia, jasmin, orange flower, and tuberoses.

Macassar Oil.—Oil of ben, one gallon; oil of noisette, half a gallon; strong alcohol, one quart; attar of rose, two drachms; attar of bergamot, three ounces; attar of portugal, two ounces; and tincture of musk, three ounces; mix together, digest with alkanet root—for color—in a stoppered bottle for a week, then strain and bottle.

Morfil's Hair Tonic.—Seald black tea, two ounces, with one gallon of boiling water; strain, and add three ounces of glycerin; tincture eantharides, half an ounce; and bay rum, one quart. Mix well by shaking, and then perfume.

Shampoo Liquor.—This excellent wash for the hair is made by dissolving carbonate of ammonia, half an ounce, and borax one ounce, in one quart of water, and adding thereto two ounces of glycerin, New England rum three quarts, and one quart of bay rum.

The hair having been moistened with this liquor, it is to be shampooed with the hands until a slight lather is formed; and the latter being then washed out with clear water, leaves the head clean, and the hair moist and glossy.

PREPARATIONS FOR THE TEETH.—These preparations should be compounded of materials, which, while cleaning the teeth without injury to the enamel, will also be antiacid, antiscorbutic, and tonic in their action upon the gums.

Poudre Détersive Dentifrice.—Willow charcoal and white sugar in impalpable powder, each eight ounces; calasay bark in impalpable powder, four ounces; mix thoroughly in a mortar, sift through the finest bolting cloth, and perfume with a mixture of attar of mint, two drachms, attar of cinnamon, one ounce, and tincture of amber, half an ounce.

Camphorated Chalk.—Precipitated carbonate of lime, one pound; powdered orris root, three and a half pounds; powdered camphor, quarter of a pound; reduce the camphor to fine powder by triturating it in a mortar with a little alcohol; then add the other ingredients, and when the mixture is complete, sift through the finest bolting cloth.

Morfil's Dentifrice.—Powdered willow charcoal, four

ounces; cinchona bark and sugar of milk, in powders, each one pound; old transparent soap, in powder, four ounces; mix in a marble mortar, sift through the finest bolting cloth, and perfume with attar of orange flower, one ounce.

Rose Tooth-powder.—Precipitated carbonate of lime, one pound; powdered orris, half a pound; rose pink, two drachms. Mix together; sift and perfume with attar of roses, one drachm; and attar of santal, twenty drops.

Another Dentifrice.—Precipitated carbonate of lime, one pound; powdered borax, half a pound; powdered myrrh, four ounces; powdered orris, four ounces. Mix, and sift through finest bolting cloth.

Opiate Tooth-paste.—Honey, powdered orris, and precipitated carbonate of lime, each half a pound; rose pink, two drachms. Rub into paste with simple sirup, and perfume with attars of cloves, nutmeg, and rose, each half an ounce.

Eau Botol.—Tincture of cedar wood, one pint; tincture of myrrh and rhatany, each four ounces; attar of peppermint, five drops. Mix.

Violet Mouth-wash.—Tincture of orris, essence of rose, and alcohol, each eight ounces; attar of almonds, five drops. Mix.

Cologne Tooth-wash.—Eau de cologne, one quart; tincture of myrrh, four ounces. Mix.

Caçhou Aramatisée.—These popular pastilles for perfuming the breath are thus made:—Dissolve three and a half ounces of extract of liquorice in four ounces of water, by the heat of a water-bath, and add of pulverized gum arabic half an ounce, and Bengal catechu, in powder, one ounce. Evaporate to the consistence of an extract, and then mix in, thoroughly, powdered mastic, charcoal, cascarilla, and orris root, each half a drachm. When the mass has been reduced to the proper consistence, it is to be removed from the fire, treated with attar of peppermint, thirty drops; tinctures of ambergris and musk, each five drops; poured out upon an oiled slab, and rolled to a very thin sheet. After cooling, blotting paper is pressed upon it to absorb any adhering oil; and the surfaces are then moistened with water, and covered with silver leaf. When dry it is to be divided into small bits of the size of a fenugree seed.

POWDERS.—Powders for the hair and skin have almost gone out of use. The basis of them is either powdered orris, or fine dry pearl starch. The perfume of the finest kinds is imparted by stratifying starch with fresh flowers, after the manner of enfleurage with fat. The flowers are subsequently separated by sifting. The simple perfumed powders thus obtained, by judicious admixture, form compound or bouquet powders. The tediousness and expense of this process prevent its general employment. The common mode is to scent by the direct addition of extracts or essential oils, or else to mix in powdered fragrant material with the orris or starch. The following formulæ will explain the manufacture of them.

Violet Powder.—Wheat starch, twelve pounds; powdered orris, two pounds. Mix together, and add attar of lemon, half an ounce; attars of bergamot and cloves, each two drachms.

Poudre d'Iris.—Powdered orris root, twelve pounds;

powdered bergamot, peel, and acacia flowers, each eight ounces; powdered clove, half an ounce. Mix and sift.

Prepared Bran for the hair.—Powdered wheat bran, one pound; powdered orris, two ounces. Mix and sift.

Poudre Noir.—for the hair.—Starch and orris in fine powder, each eight ounces; charcoal and ivory black, in fine powder, each one ounce. Mix and sift.

Poudre Blonde.—for the hair.—Finely powdered starch and orris, eight ounces each, as in the preceding, but with yellow ochre for the coloring matter.

Poudre à la Vanille Brune.—for the skin or for sachets.—Powdered vanilla, rose leaves, lump storax, benzoin, rhodium, pallisandre and ebony woods, each one pound; powdered cloves, two ounces; powdered musk, two drachms. Mix together with three pounds of starch; sift, and add a few drops of extracts of tubero-rose and jessamine.

Poudre à l'Œillet Composé.—for the skin or sachets.—Powdered rose leaves and orris root, each three pounds; powdered bergamot peel, one pound; powdered cloves and cinnamon, each six ounces; powdered acacia and orange flowers, each eight ounces; starch, three pounds.

ROUGES.—Paints or rouges are the means by which the natural color of the skin may be heightened or changed. They are, however, objectionable preparations, and the use of them extends very little beyond the theatres, where they are employed to produce stage effect.

French White.—This is the mineral talc, or French chalk, finely levigated and bolted. It forms the basis of the most harmless rouges. Perfume is added as may be desired.

Pearl White.—Pure oxide or subnitrate of bismuth in powder. This pigment darkens in atmospheres containing sulphide of hydrogen. One ounce triturated with four ounces of orange-flower water makes liquid white.

Pearl Powder.—Precipitated carbonate of lime, finely bolted and perfumed. The French add oxides of zinc and bismuth, each one ounce to the pound of chalk.

Carmine Rouge.—Finely bolted talc, four ounces; carmine, two drachms. Mix together with a little warm and dilute solution of gum tragacanth. For lighter shades, the proportion of carmine must be increased. For commoner pastes, rose pink replaces the carmine as coloring matter. It may be made into a pomade.

Bloom of Roses.—Powdered carmine of the best quality, two drachms, digested with strong ammonia, four ounces, in a tightly stoppered bottle for two days, at the ordinary temperature of the atmosphere. Then add rose water, one pint, and essence of rose, four ounces. After a week's repose, the upper stratum of clear liquid may be decanted from the subsident matter, and bottled.

Fard Bleu d'Azur.—Talc and ultramarine, finely bolted, equal parts, triturated with a solution of gum tragacanth into a stiff paste.

TOILET SOAPS.—To this class belong the finer kinds of scented soaps, which have emollient properties. They are rarely made direct by the perfumer, the body or basis being a well-selected white soap, subsequently

cleansed and purified. For the choicest grades, the body should be made of a mixture of olive and sweet almond oils, as the fat stock. Lard and beef tallow make the next best stock; and for palm soap a small quantity of bleached palm oil is to be added to them. Cocoa oil and pale yellow rosin saponaceous matters also enter into the composition of certain toilet soaps. These body-soaps may be obtained as wanted from any well-conducted soap factory. To be adapted to the purposes of perfumery they must be perfectly neutral, firm, free from unpleasant odor, and all tendency to *crust* in cold, or *sweat* in damp weather. They should, moreover, give a rich lather without wasting too rapidly in the water. Soaps, generally, in their original condition, are usually deficient in many of those points; and must, for the purposes of perfumery, undergo a refining process, which is as follows:—

The soap, as purchased in bars or blocks, being piled upon the shelf of the rasping machine, is next placed in the hopper, and as the wheel revolves, knives come against the soap and cut it into meal, which falls into the reception box beneath. It is now in a state fit to be melted readily, for which purpose it is transferred to the steam bath before mentioned at pages 669 and 670, and mixed with rose and orange-flower waters, each half a gallon, to every hundred pounds of soap. The steam being let on, and the containing kettle covered, its contents become gradually fluid, and in this state must be stirred with a *crutch*, which is a long stick having the form of an inverted T, until the paste becomes uniformly consistent and smooth throughout. It is then allowed to cool, again melted, but without fragrant water, and crutched as before. When the contents of the vessel comprise several kinds of soap, great care must be observed not to put in all at once, but to add and melt each successively, and to crutch constantly, so as to effect an intimate mixture. When the paste begins to cool, coloring matter as may be desired is then added; and subsequently the perfume, which is reserved to the last, to avoid any unnecessary loss by evaporation from the hot paste. A portion of glycerin might also be added at this stage, with great advantage to the soap, as that liquid imparts an eminent emollient property.

When extracts or bouquets are used, as for scenting the finest kinds of soap, they must be added to the compound in meal, and incorporated with the mass by kneading it with the hands; for the application of heat would impair the delicacy of the odor, as well as occasion loss by its evaporation. In large establishments, this is done by passing the meal repeatedly between marble rollers.

The soap is now ready to be put into the cooling frames, which is a rectangular well made of a series of wooden frames, resting successively one upon the other. In a day or two it is sufficiently hard to be cut into bars and tablets of the size of the sections of each frame, which are fitted by means of a piece of brass wire, which are set up edgewise, and left for several days to dry, and are then barred by means of a wire. The sections or *lifts* of the frame regulate the width of the bars, and the gages adjust their breadth—these latter being made so as to cut bars

or squares of four, six, eight, or any required number to the pound of soap. The bars are further subdivided into tablets, and subjected to pressure for the purpose of imparting solidity, and ornamenting the exterior with some appropriate device, or impressing upon it the maker's name. Moulds for this purpose are shown by Fig. 395, and they may be varied in form and inscription according to taste; but the character of the latter is generally floral or medallion. The press is of ordinary construction, with spiral springs to throw out the soap tablet from the die box as soon as it is pressed. The box is movable, so that the die may be changed at will. In some factories the pressure is more effectually accomplished by means of a steam-hammer, which is made to give three successive blows, directly vertical, to each tablet of soap. Savonettes, or soap balls, are shaped by rotating blocks of soap upon a soap-scoop made of brass with sharp edges.

Fig. 395.



Almond Soap.—This is a very white soap, which, when genuine, is made by the cold process hereinafter described, and from pure oil of sweet almonds. The kind, however, generally met with is made as follows: white curd soap, one hundred pounds, and cocoa-nut oil, fifteen pounds; purified as before directed, and perfumed with a mixture of attar of bitter almonds, one and a half pounds, and attars of cloves and caraway, each eight ounces.

White Windsor Soap.—The genuine old white windsor is made from a body of which a mixture of lard and olive oil is the fat stock; and attars of caraway, lavender, and rosemary, constitute the perfume. The modern windsor soap is made from fine white curd soap, one hundred and fifteen pounds; cocoa-nut oil soap, twenty pounds; perfumed with a mixture of attar of caraway, one and a half pounds; attars of thyme and rosemary, each eight ounces; and attars of cassia and cloves, each four ounces.

Brown Windsor Soap.—Curd soap, one hundred pounds; cocoa-nut oil, and pale yellow rosin soaps, each twenty-five pounds; color with caramel, eight ounces; and perfume with a mixture of attars of caraway, cloves, thyme, cassia, petit-grain, and lavender, each eight ounces. MORFIT'S oleic soap, of first grade, is peculiarly adapted as body for brown windsor soap, as it gives a rich lather, and is very smooth, and highly emollient. Moreover, it retains its normal moisture for a great length of time.

Savon au Miel—Honey Soap.—White curd soap, forty pounds; melted and crutched with white honey, ten pounds; storax, two pounds; and powdered benzoin, one pound.

An imitation honey soap is made by melting together pale yellow soap, one hundred pounds; soft soap, fourteen pounds; and perfuming with attar of citronella, one and a half pounds.

Frangipani Soap.—Curd soap, colored brown with caramel, seven pounds; perfumed with a mixture of attars of neroli and vitivert, each four ounces; attar of rose, two drachms; attar of santal, one and a half

ounces; and civet, two drachms. The latter is to be previously triturated with the attars.

Savon à la Rose.—Rose soap is made from a mixture of olive oil soap, sixty pounds; and curd soap, forty pounds; colored with one pound of finely bolted vermilion. The perfume consisting of attars of rose, six ounces; attars of santal and geranium, each one ounce; and tincture of musk, eight ounces; must be added to the cold soap in meal, and incorporated by kneading. The oil soap may be replaced by curd soap, but the quality of the rose soap will not then be so fine.

Savon au Bouquet.—White soap, sixty pounds, perfumed in the cold with eight ounces of an extract bouquet; or in warm paste, with a mixture of attar of bergamot, eight ounces; attars of cloves and sassafras, each half an ounce; attar of thyme, one ounce; attar of neroli, one ounce. The soap body must be previously colored brown with one pound of caramel. The soap scented with the attars is inferior to that having the extract bouquet as perfume. The perfume, and with it the title of the soap, can be varied according to the caprice of fashion.

Poncine Soap.—Curd soap, fifty pounds; cocoa nut oil soap, the same quantity, melted to paste and crutched with ten to twenty pounds of finely bolted pumice-stone powder. The perfume is a mixture of attars of thyme, cassia, caraway, and lavender, each one pound.

Spermaceti Soap.—The genuine spermaceti soap is superior to all others in emollient properties; but it is rarely made from pure stock, owing to the difficulty in saponifying it. As generally vended, it consists of white curd soap, fourteen pounds; perfumed with a mixture of attars of bergamot, two and a half pounds, and attar of lemon, eight ounces.

Palm Soap.—Curd soap, made of a mixture of one-half lard, one-third bleached palm oil, and the remainder olive oil or spermaceti, constitutes the body of palm soap. Its natural odor is that of the violet, which is sometimes stimulated by the addition of a little attar of portugal, with a lesser portion of attar of cloves.

Floating Soap.—All the hard soaps increase in bulk by mechanical batting of the paste; the loss of density thus produced gives them the property of floating in water. The batting or whipping is best accomplished by means of a churn-twirl, rotating on a pivot in the bottom of the melting-pan, and put in motion by a handle.

Transparent Soap.—This amber-looking soap is made by dissolving hard white soap, previously reduced to meal and thoroughly dried, in alcohol of 66° Twaddell. The steam-bath before described, fitted with a still head, makes a very appropriate containing vessel. The alcohol and soap are taken in about equal proportions; and as the solution proceeds, any spirit which may distil over must be allowed to condense in a worm, and collect in a receiver. The heat should not exceed 212°. After solution, the whole must be allowed repose for settling, after which the clear, supernatant fluid is to be drawn off from the sediment into wooden frames, or globular moulds of britannia metal, if it is desired to cast it in ball form. Previous to settling, it may be colored as desired—red, with tincture of alkanet; yellow, with tincture of turmeric;

orange, with a mixture of the two tinctures; green, with tincture of chlorophyle; and blue with tincture of indigo carmine. Transparent soap is rather translucent when first made, and does not clear until perfectly dry. The perfumes are the same as for the other soaps.

SOAPS BY THE COLD PROCESS.—All the foregoing soaps are made by boiling the fat stock with alkali; but toilet soap may also be made extemporaneously without much heat and the so-called little pan process. Many of the French and American perfumers manufacture their soaps in that way. The lies are necessarily very strong, and should be of 66° Twaddell. Cold soaps are very white, and also very hard, as they do not contain any excess of water.

White Soap.—Lard forty pounds, and caustic soda lie, of 64° Twaddell, twenty pounds. Melt the fat by a heat not exceeding 150°, and add, during constant stirring, ten pounds of the lie. After one hour's manipulation with the stirrer, the heat being continued all the time at a moderate degree, the remaining ten pounds of lie are to be added. When the paste has become smooth and uniform throughout, it is transferred to a cooling frame, perfumed, and left in a room of moderate temperature for a few days to set and ripen. It is then ready to be cut into tablets and pressed.

Almond Soap.—Genuine almond soap is made from oil of sweet almonds, fifty pounds; and soda lie of 66° Twaddell, twenty-five pounds, the latter being gradually added to the former at a temperature between 125° to 150°, and the whole stirred constantly until the mixture has a pasty consistence. It is then transferred to a cooling frame, perfumed with attar of bitter almonds, and then left for several days to set and ripen.

Soft Soaps.—These differ from the hard soaps in having potassa in place of soda as their alkaline base. They are all more or less pasty or gelatinous; and they may be made either by the boiling or cold process. Of the soft soaps used in perfumery, that known as *fig soap* is, however, the only one that is boiled.

Fig Soap.—The fat stock is chiefly oil—generally olive oil—with the addition of a little tallow to give it the granular appearance called *fig*.

Shaving Cream.—This saponaceous compound is made by melting twenty pounds of lard in the steam-bath, at a temperature of 212°, and then letting five pounds of caustic potassa lie, of 66° Twaddell, run in *very slowly*, during constant stirring and batting with a wooden paddle. The heat is continued all the time; and after a while, when the paste becomes thick, five pounds more of lie are added in the same manner. After several hours' stirring the paste becomes firm, and is then finished. It is then transferred to a mortar and triturated, until the soap becomes homogeneous throughout, and assumes a pearly appearance. Attar of almonds is the perfume for almond cream, and attar of rose for the rose cream, and they are dissolved in a little alcohol, and added during the trituration. The rose cream is colored at the same time with a little tincture of alkanet.

Rypophagon Soap.—This is a mixture of equal parts

of pale yellow rosin soap and fig soft soap, perfumed with attars of anise and citronella.

According to PIÈSSÈ, British India and Europe consume annually, *at the lowest estimate*, upwards of one hundred and fifty thousand gallons of perfumed spirit, under various titles, such as eau de cologne, lavender water, esprit de rose, *et cetera*. Some idea of the commercial importance of this art may be formed, when one of the large perfumers of Grasse and Paris employs yearly eighty thousand pounds of orange flowers, sixty thousand of cassia, fifty-four thousand of rose leaves, thirty-two thousand of jasmin blossoms, twenty thousand of violets, and sixteen thousand pounds of lilac, besides rosemary, mint, lemon, citron, thyme, and other plants in larger proportion.

The Editor cannot conclude this monograph without expressing his thanks to Dr. CAMPBELL MORFIT of New York for the valuable assistance he has rendered him during its compilation. Professor MORFIT is the author of one of the best books on this subject which has recently appeared; and being the first technological chemist in America, the Editor, although personally unknown to him, feels the more gratified for his having volunteered his aid in this article, which is sure to prove interesting to all readers, whether scientific or otherwise; for, as shown in the introductory notice, perfumes, in the early ages of the world, were in constant use, and had the high sanction of Scriptural authority.

PHOSPHORUS.—*Phosphore*, French; *phosphor*, German; *phosphorus*, Latin.—This truly remarkable substance is one of the elementary bodies. It occurs abundantly in both kingdoms of nature, not, however, in the free state, but always in combination, usually as phosphoric acid united to earthy and metallic bases. Its intense affinity for oxygen would not allow it to exist in nature in an isolated form; for on exposure to the air, even at the ordinary temperature, it undergoes a slow combustion, and is converted into phosphorous and phosphoric acid. At a very slightly elevated heat it takes fire, and is resolved entirely into phosphoric acid. Nor is phosphoric acid met with naturally uncombined, its powerful reaction upon the bases causing it to enter quickly into combination. Amongst phosphorus compounds, the most important are those which phosphoric acid forms with lime and magnesia, and these are widely distributed throughout nature. In this condition it is found in unstratified rocks, and in the lavas of more recent date. As these disintegrate, and crumble down into fertile soil, the phosphates pass into the organism of plants, and ultimately into the bodies of the animals to which these latter serve as nutriment. Phosphate of lime constitutes by far the greatest part of the hard matter of bones, and consequently fulfils a very important part in the structure of the animal frame, communicating stiffness and inflexibility to the bony skeleton. Phosphorus is also an ingredient, in some unknown form of combination, of animal and vegetal fibrin and albumen. It is likewise found in the brain, and in the soft roe of the carp, though in what particular condition it exists is uncertain. In the urine and excrements it is also invariably present. In the mineral kingdom, it

is found principally as phosphate of lime—known to mineralogists as apatite—as phosphate of magnesia, as phosphate of alumina, or wavelite, and as phosphates of lead and copper, *et cetera*.

The term phosphorus—derived from two Greek words signifying *light-producer*—was applied by the older chemists to every species of substance capable of becoming luminous without the application of heat. It is now retained only by the one simple substance under consideration.

HISTORICAL NOTICE.—Amongst the many important discoveries made by the alchemists in their pursuit of the philosopher's stone, that of phosphorus holds a very high position. It was first obtained, in 1677, by BRANDT, a tradesman of Hamburg, while engaged in prosecuting researches upon urine, with the view of extracting from it the mysterious agent that would effect the transmutation of the baser metals into gold. BRANDT partially explained the secret to KUNCKEL, a German chemist with whom he was acquainted, and who subsequently succeeded in obtaining it even more pure than had been done by BRANDT. He continued to prepare it, and it soon became known as KUNCKEL'S phosphorus, to distinguish it from other bodies possessing the property of luminosity. In 1676 KUNCKEL published a description of it, and was afterwards considered as one of its discoverers.

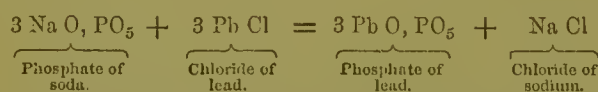
In England, the celebrated BOYLE, having seen phosphorus in the hands of KRAFT of Dresden, who had purchased the secret from BRANDT, and knowing that it was extracted from some matter appertaining to the human body, commenced his investigations, which, after a year's labor, were crowned with success. In 1680 an account of the new substance was published in the Philosophical Transactions, and it became known under the name of English phosphorus. BOYLE communicated his process to GODFREY HAUKWITZ, who prepared it under his direction in London, in large quantities; and after the death of BOYLE and KUNCKEL, HAUKWITZ was alone in possession of the secret and the trade in this substance. Up to this time it was extremely rare, being found only amongst the cabinet curiosities of the rich; and for the next fifty or sixty years its great price prevented its employment in any branch of art or manufacture. At last, in 1737, a stranger came to Paris, and sold to the French government a process for its preparation, which HELLOT, conjointly with GEOFFROI, DUFAY, and DUHAUSEL, was charged to submit to the test of experiment. The process was successful, and a report of it was published in the Memoirs of the Academy for the year 1737. By this method, also, it was extracted from urine, and although the process succeeded it could never have been employed on the large scale. It was besides tedious and offensive. To understand the difficulties it will be sufficient to say, that, after a protracted series of operations, the above-mentioned chemists obtained from five hogsheads of urine, thirty-eight pounds of the residue on evaporation, the whole of which yielded only four ounces of phosphorus, and by means of four distillations.

Experiments were afterwards made by MARGRAAF, FOURCROY, VAUQUELIN, and others, to render the

process of extracting it from urine more easy, but this process was entirely relinquished when SCHEELÉ and GALIN discovered the presence of phosphoric acid in the bones of animals. It is from bones that phosphorus is still extracted at the present day. It is prepared as an article of manufacture in large quantity in London and Paris. KANE has calculated that in the latter city alone, about two hundred thousand pounds are yearly produced. In Germany, also, it is manufactured on a large scale; one establishment at Carlsruhe—that of OTTO PAULI—producing annually, amongst a long list of other chemical substances, sixty hundred-weight of this one article. Its ready inflammability has always made it a subject of popular interest, while the singularity, importance, and variety of its compounds, have drawn to them no ordinary share of the attention of chemists. The introduction of lucifer matches has enormously increased its consumption; indeed, at least ninety-five per cent. of the whole quantity produced is absorbed by this manufacture.

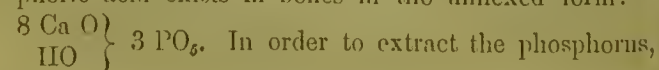
PREPARATION.—All the processes for obtaining phosphorus are founded upon the deoxidation of phosphoric acid— PO_5 —by means of carbon.

BRANDT and BOYLE evaporated urine to a thick creamy consistence. This was afterwards distilled, either *per se*, or after being mixed with sand or charcoal powder. In this process the carbon—either that which results from the charring of the organic matter contained in urine, or that which is added to it—decomposes the portion of the phosphoric acid which is in combination with ammonia, while that which is combined with the soda remains unaltered. MARGRAAF evaporated urine to the consistence of honey, then added one-tenth of chloride of lead, and half its weight of charcoal powder. The mass was afterwards thoroughly desiccated, and then distilled. In this case the chloride of lead and phosphate of soda mutually decompose, yielding phosphate of lead and chloride of sodium:—



GIOBERT precipitated urine, without previous evaporation, with a soluble salt of lead. The precipitate of phosphate, sulphate, and chloride of lead was collected, well washed, and mixed with a fourth of its weight of powdered charcoal. The mixture was then exsiccated and distilled. The great advantage in the processes of MARGRAAF and GIOBERT was, that an equal quantity of urine yielded nearly twice as much phosphorus as the process of BOYLE and BRANDT, in consequence of the decomposition of the phosphoric acid originally in combination with soda, and which in the process of the latter chemists would remain unaffected.

After the discovery of phosphoric acid in the bones of the vertebrata, the old methods of extracting phosphorus from urine were totally abandoned, and it is now obtained almost exclusively from bones. Phosphoric acid exists in bones in the annexed form:—



the bones are first thoroughly calcined, that is, heated to redness, with contact of the air, until the organic matter is entirely removed. The bone ash thus obtained is reduced to powder, and to every three parts are added two of concentrated sulphuric acid, and sixteen or eighteen parts of water. By this treatment a portion of the lime is separated as sulphate, and an acid phosphate of lime is produced, which dissolves in the supernatant liquid. After the separation of the sulphate by decantation and filtration, the phosphoric solution is concentrated by evaporation to a thick sirupy consistence. A quantity of charcoal powder, equal to one-fourth of its weight, is then added, and the pasty mass is exposed to a strong heat, nearly to redness, till perfectly dry. The desiccated mass is then transferred to a stoneware or iron retort, connected by a wide elbow-shaped copper tube with a receiver containing water, into which the tube dips about a line. Another smaller tube, open at both ends, is attached to the receiver, to convey the uncondensed gases into the chimney. Heat is now applied, and is gradually increased to whiteness. The superphosphate of lime, in contact with charcoal, is decomposed, the lime retaining only the quantity of phosphoric acid necessary to reconstitute bone earth. The excess of acid, and the water still remaining in the mass, are deoxidised by the charcoal, and the results are carbonic oxide, hydrogen, and phosphorus. The phosphorus gradually rises in vapor, distils over, and is condensed in yellow drops in the water contained in the receiver, at the same time that the gases escape by the smaller tube into the chimney.

The theory of this operation is very simple, but in practice many difficulties occur, and the requisite precautions will be pointed out in the following detailed account of the process.

Preparation of the Bone Ash.—The bones usually employed in this manufacture are those of oxen, of sheep, or of horses. The bones of sheep are preferred, as the ash which they yield is less compact, and more easily attacked by an acid. They contain, besides sulphosphate of lime, carbonate of lime, and a small per centage of other salts, as phosphate of magnesia, chloride of sodium, fluoride of calcium, &c. &c.: also a large proportion of animal matter, estimated at from thirty-three to fifty per cent., according to the kind of bone, and the age of the animal. The following analysis of the bones of the ox is by BERZELIUS:—

	Centesimally.
Animal matter soluble by boiling, and vascular substance,.....	33.30
Phosphate of lime, with a little fluoride of calcium,.....	57.35
Carbonate of lime.....	3.85
Phosphate of magnesia.....	2.05
Soda, and a little chloride of sodium,.....	3.45
	100.00

The object of the first operation is to cause a complete separation of the animal matter. This is usually effected by calcination. The process is conducted in a large reverberatory furnace as follows:—The fire is first well kindled; a quantity of bones are then introduced by the opening in the dome of the furnace. When these are well inflamed, a further supply is added until the furnace is about half filled. A strong

draught is created by placing on the cupola, surrounded by a cone, a stove pipe, more or less elevated, and which is directed into the chimney. The operation now goes on of itself, and the combustion is very complete. When concluded, the ash is drawn out at the furnace door, and a fresh charge introduced at the upper opening, being careful not to add a too great quantity at one time, and also to maintain the necessary draught, so that the operation may not be suspended. The calcination is effected at little expense, as the bones themselves yield the necessary combustible matter. When first heated, they become black, owing to the disengagement of hydrogen, oxygen, and nitrogen gases, and the consequent separation of charcoal. A considerable time is required to remove the whole of the charcoal from the osseous mass; and if, when the ash is drawn out, many black portions remain, they are returned to the kiln, and recalcined.

Very frequently bones are used in this manufacture from which the soluble gelatinous matter has been previously extracted. When these residues are collected in heaps, a rapid fermentation ensues, and they become heated and perfectly dried. They are afterwards burned in a reverberatory furnace, or one of similar construction. Before introducing the bones, the bed of the furnace is heated to redness. They are submitted to the action of the flame for the space of twenty hours, at the end of which time the incineration is usually complete.

The incombustible residue of these operations consists of about eighty to eighty-two per cent. of a phosphate of lime— $6\text{CaO} + 3\text{PO}_5$ —fifteen to seventeen of carbonate of lime, and two or three of sand, earthy matter, chloride of sodium, *et cetera*. According to GRAHAM, bone earth contains two distinct phosphates of lime, both tribasic, but in one of which an atom of lime is replaced by one of water. He gives as its formula— $2(3\text{CaO}, \text{PO}_5 + \text{HO}) + (\text{HO}, 2\text{CaO}, \text{PO}_5 + \text{H}_2\text{O})$. The calcined bones are ground to fine powder and sifted. The powder is greyish-white, and almost tasteless.

Second Operation.—The object of the next process in this manufacture is to transform the insoluble calcareous phosphate into the soluble superphosphate. This conversion is effected by means of sulphuric acid, which separates a portion of the base in the form of the nearly insoluble sulphate of lime. The sulphuric acid also decomposes entirely the carbonate of lime present, producing the same difficultly soluble salt. The operation is effected in a leaden cistern or in a wooden tub lined with lead. To three parts by weight of the bone ash are added two of concentrated sulphuric acid, and from fifteen to twenty parts of water, constantly stirring with a wooden spatula. A lively effervescence ensues, owing to the escape of carbonic acid. When this has subsided, the whole is transferred to a copper boiler, heated to the point of ebullition, and to promote decomposition, continued at this temperature for twenty-four hours. The liquid requires to be constantly agitated, to prevent the concretion of the mass, which, if allowed, would protect a portion of the superphosphate from the action of the acid. When completely decomposed, the mixture is suffered to remain at rest

for ten hours, so that the sulphate of lime may subside. The supernatant liquid is afterwards drawn off by means of a leaden siphon, and conducted through leaden pipes to the filter, consisting of a conical linen bag of close texture, which retains the sulphate of lime, and allows the solution of acid phosphate to pass through. The residue itself is then thrown upon the filter and strongly pressed, and afterwards thoroughly washed with successive portions of boiling water. The filtrate is now concentrated, by evaporation in a copper boiler, to one-fourth of the original quantity, and again filtered to remove the portion of sulphate of lime which has become insoluble; the evaporation is then resumed till the liquid has a sirupy consistence. The sirup, which contains the acid sulphate of lime, the excess of sulphuric acid, and a little sulphate of lime, is gradually mixed with a quantity of powdered charcoal, about one fourth of the original weight of the bones. The mass, after being evaporated to dryness, is further dried in a cast-iron kettle, at a nearly red heat, and with constant stirring with an iron spatula. During this process, the greatest part of the water is disengaged; a portion of the excess of sulphuric acid is also set free; the remainder, by the action of the charcoal, is decomposed, and sulphurous and carbonic acids are liberated.

Distillation.—The perfectly dry mixture of acid phosphate of lime and charcoal is ground to fine powder in an iron mortar, and transferred as quickly as possible into the retorts. These, which are of earthenware, are arranged side by side in a reverberatory furnace, as shown in Fig. 396. The neck of the retort fits into the

Fig. 396.



tubulure of a copper receiver half filled with water, and furnished with a tube for the escape of the gas formed during the distillation. Each retort has its own receiver, and all the receivers are placed in a trough filled with water, at the temperature of about 110° , and kept at that temperature, in order that the phosphorus distilling over may not solidify and obstruct the tubulure. In performing the distillation, a very high temperature is required. The furnace should therefore be sufficiently capacious to hold a body of coke or charcoal piled above the retort. Earthenware retorts at a red heat become permeable to the vapor of phosphorus, and consequently require to be well and carefully luted externally. For this purpose a mortar, composed of clay and horse dung, may be applied, or, still better, a mixture of freshly slaked lime and solution of borax. This mixture should be laid on with a brush in two or three successive coats, and forms, according to BRANDE, an excellent vitriable lute. The copper tube opening into the receiver, and into which the beak of the retort is inserted, should be of considerable size, and so bent as to dip perpendicularly into the water, otherwise it will be apt to become plugged up by congealed

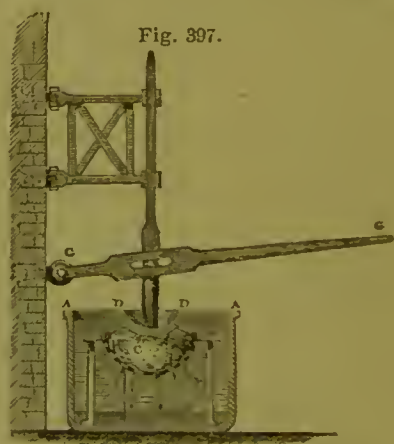
phosphorus. It must also dip so little, that by no condensation could the water be forced back into the retort. The heat of the furnace in which the retorts are placed should be very slowly raised, allowing at least three hours to heat to redness; afterwards it is urged vigorously till all disengagement has ceased, the process requiring from fifteen to thirty hours, according to the size of the retorts. The superphosphate of lime, although dried at a high temperature, retains chemically-combined water, which is liberated by the superior heat of the furnace. At first, therefore, a mixture of air and steam is disengaged; afterwards, when the charcoal becomes incandescent, a mixture of hydrogen and carbonic oxide, evidently proceeding from the decomposition of the water by the hot charcoal— $\text{HO} + \text{C} = \text{H} + \text{CO}$. When the retort has attained a bright red heat—that is, after the lapse of about four or five hours—the nature of the gaseous products is changed. The superphosphate of lime is decomposed into basic or subphosphate of lime, and phosphoric acid. This last, in contact with incandescent carbon, yields phosphorus, which rises in vapor, distils over, and condensing in the liquid form in the tubulure, flows down and collects under the surface of the water. The phosphorus is accompanied by a mixture of carbonic oxide and phosphide of hydrogen, the last inflaming spontaneously on contact with the air. These two gases continue to be produced during the whole operation. DUMAS considers it an unsettled question, whether the gas evolved is really phosphide of hydrogen, and if it is not carbonic oxide saturated with the vapor of phosphorus, as a small quantity always escapes condensation, and this is sufficient to render carbonic oxide spontaneously inflammable by contact with the air. The disengagement of gas enables one to trace the progress of the operation, and when it has entirely ceased, the process is terminated. In the retorts are found a subphosphate of lime—having precisely the same composition as the original bone phosphate, $6\text{CaO} + 3\text{PO}_5$ —and also the redundant charcoal. The lime of the phosphate acts a most important part in fixing the phosphoric acid, which, if not so combined, would distil over long before the heat was sufficiently high for decomposition.

The proportion of the various ingredients used in the production of phosphorus, is varied by different manufacturers. FUNCKE used, for one hundred parts of bone ash, ninety parts of concentrated sulphuric acid, and nine hundred and fifty of water. This mixture is digested for a considerable time in a leaden vessel, then transferred to a linen filter. The filtrate is afterwards evaporated to the consistence of sirup, mixed with twenty parts of charcoal powder, and dried. By distillation this mixture yields ten parts of phosphorus. NICOLAS used equal weights of bone ash and oil of vitriol. Various other methods have also been proposed for procuring phosphorus from bone ash. SCHEELE dissolved the ash in nitric acid, and precipitated the lime by sulphuric acid. The rest of the process is conducted as above. FOURCROY and VAUQUELIN prepared acid phosphate of lime according to NICOLAS' method, and precipitated its aqueous solution with acetate of lead. The resulting phosphate of lead was afterwards distilled with one-sixth of its weight of

charcoal. BERZELIUS dissolved bone ash in warm nitric acid, and precipitated the hot solution with acetate of lead. Native phosphate of lead may also be employed, provided it is free from arseniate.

Purification.—The phosphorus obtained by any of the above processes is never in a state of purity, as it passes into the receivers. The ordinary impurities are adhering charcoal, a reddish-brown phosphide of carbon formed during the process, and another reddish-looking substance, originally supposed to be an oxide of phosphorus, but ascertained by SCHÜRTER to be phosphorus in an allotropic condition. Phosphorus, otherwise pure, generally contains a small quantity of this amorphous modification of the element. Arsenic is also frequently present, in consequence of the acid used in its preparation having been formed by the combustion of arsenical sulphur, or pyrites. WITTETOCK found in one sample of phosphorus 0.76 per cent. arsenic. The same chemist examined a sample of phosphorus obtained from France, the coating of which was greyish-yellow instead of white. It appeared, when freed from this coating, of a dark-red color by transmitted light. Its fractured surface was almost black, and it retained this color when melted and slowly solidified. Besides arsenic he found it to contain bismuth, lead, iron, copper, and a large quantity of antimony.

Most of the impurities may be separated by simple fusion in hot water, and afterwards pressing through buckskin, or still better, chamois leather. The operation is effected in the apparatus represented in Fig. 397. The phosphorus is first agglomerated by melting it in a water bath at 140° . When it has again solidified by cooling, it is wrapped in a perfectly clean



and well-moistened chamois skin, C, which is then tied up, and immediately plunged into a copper colander, placed in the middle of another vessel, A, filled with water, heated to about 120° Fahrenheit. When completely fused, the bag of skin is pressed upon by a wooden capsule, D D, by means of the lever, G G, increasing the pressure very gradually. The melted phosphorus passes through the pores of the skin, and collects in the liquid form at the bottom of the vessel.

PAYEN gives a description of a process by which the purification is rendered more complete, obviating at the same time all danger in the manipulation. It consists in causing it to pass, when in a state of fusion, through granular animal charcoal. The apparatus consists of a cylindrical vessel provided with a false bottom,

pierced with small holes, on which is laid the charcoal in a layer to the height of six or seven inches. The cylinder is then filled to two-thirds with water heated to 140° Fahrenheit, and the phosphorus, as taken from the receivers, is introduced. Being quickly melted, it passes spontaneously through the charcoal filter, and collects under the false bottom. It is afterwards strained by hydrostatic pressure through chamois skin.

Several other methods have been followed to effect the separation of the red amorphous phosphorus. It may be removed by digestion for a considerable time, and with frequent agitation, in very dilute nitric acid, or in chlorine water, contained in a cask fitted with a gas delivering tube, which dips under water.

The redistillation of phosphorus is occasionally resorted to as a means of purification. On account of its excessive inflammability, the process demands great care and attention. DUMAS recommends for the distillation of phosphorus a double U-shaped tube, into the first curve of which the phosphorus to be distilled is placed, the other curve serving in place of a receiver. The arrangement is afterwards connected with an apparatus from which issues a current of perfectly dry hydrogen, or carbolic acid gas. The phosphorus, when submitted to heat, volatilizes, and distils over with the gas, and is condensed in the second curve of the tube, from which it is removed after being melted in hot water.

MOULDING.—Phosphorus, as usually met with in commerce, is either in the form of round sticks, or granular. The moulding into sticks is effected by allowing it when fused to flow into glass tubes. A method frequently adopted is simply to plunge a slightly conical glass tube into the phosphorus melted under water, and causing it to ascend the tube by drawing out the air by suction with the mouth, being careful to have a layer of water between the phosphorus and the mouth. When the required quantity has entered the tube, the upper end of the latter is closed with the finger, and the whole is immediately transferred to a vessel filled with cold water. The removal of the phosphorus from the tube may be accomplished by gently pushing with a stout wire through the narrow end of the tube.

A very simple, and at the same time very efficient, mode of forming phosphorus into sticks, has been contrived by SCHUBERT. By the old system, the glass tubes, into which the phosphorus was poured to solidify, were frequently broken in forcing the phosphorus out by means of wires, and the method was, moreover, attended with great loss of time. In SCHUBERT'S arrangement the melted phosphorus flows from a copper receiver into horizontal glass tubes, the one extremity of each tube being surrounded by water at a temperature above 111° ; the other by cold water. By suddenly opening a stopcock, and again quickly closing it, a small quantity of phosphorus is allowed to pass through the glass tubes into cold water contained in a cistern, and in passing it closes the tubes, leaving a projecting rough piece of phosphorus, which forms an excellent handle, whereby to draw the sticks from the tubes. The operation thus commenced, the cock is again opened, and the phosphorus drawn alternately from either tube, cut off with a pair of strong scissors, and allowed to

fall into the cistern. By this method, from fifteen to twenty pounds of phosphorus may be formed into sticks in less than a quarter of an hour.

To obtain phosphorus in the granular condition, it is caused to fall in drops into cold water. SCUBERT'S apparatus will also be useful in this operation. The cistern, is filled to about three parts with cold water, and upon the surface of this is placed a layer of water, heated to about 140° Fahrenheit, high enough to cover the glass tubes which convey the phosphorus from the boiler. This is done by pouring the hot water upon a wooden trencher, swimming on the surface of the cold water. The difference in the density prevents the cold water mixing with that at a higher temperature. The stopcock of the vessel containing the melted phosphorus is slightly opened, so as to allow it to exude in drops. These, falling through the mass of cold water, become solid, and collect in the granular condition at the bottom of the cistern. Phosphorus may also be granulated by shaking it, while in the fused state, with a warm liquid, till it solidifies. CASSARCA recommends for this purpose strong alcohol.

PROPERTIES.—Phosphorus at the ordinary temperature, when perfectly pure, is a soft solid substance, transparent and colorless. As generally found in commerce, it is of a light amber yellow color, or even reddish, much resembling in appearance imperfectly bleached wax. After rapid cooling it is yellow, and semi-opaque like horn, and has a waxy lustre. At 32° it is brittle and crystalline in its fracture. At a higher temperature it is soft and very flexible, may be several times bent in contrary directions without fracture, and is easily cut with a knife. The addition of an extremely small quantity of sulphur, even a three hundredth part, is sufficient to render it brittle. Being totally insoluble in water, it is tasteless; its solutions in other liquids have, however, an acrid disagreeable taste. Neither has it any smell, though on exposure to the air it gives off vapors, which, undergoing a slow combustion, have an odor somewhat resembling that of garlic, or of impure hydrogen. Its specific gravity at 60° is 1.77, and at 212° according to SCHRÖTTER 1.83. Its atomic weight, according to BERZELIUS, is 31.36. Many chemists, however, take it in their calculations at 32.

Exposed to heat it quickly melts. Its fusion commences at 108° , and in close vessels even at 95° . When melting it undergoes a dilatation of 0.0134 of its volume, according to GRAHAM, and immediately before fusion becomes transparent and colorless. It forms a transparent, oily-looking, colorless fluid, possessing a high refracting power. When completely fused, and allowed to cool slowly and without agitation, it remains liquid at 100° , or even at a lower temperature; and during solidification, the temperature rises to 108° . It begins to evaporate at 217.5° , and boils at 550° , forming a colorless vapor, the density of which DUMAS gives at 4.353, air being unity. Phosphorus volatilizes at temperatures considerably below its boiling point, and in small quantities even at ordinary temperatures, as well *in vacuo* as in the open air. Several gases, as oxygen, hydrogen, carbonic acid, nitrogen, *et cetera*, when placed in contact with phosphorus, become charged

with its vapor, and if boiled with water, it renders the aqueous vapor luminous.

Phosphorus is quite insoluble in water, but soluble—particularly if heated—in absolute alcohol, in chloroform, in fixed and volatile oils, in native naphtha, and most of the liquid hydrocarbons, in chloride of sulphur, sulphide of phosphorus, and in ether. Its best solvent, is, however, bisulphide of carbon, which dissolves one-fourth of its weight. Phosphorus crystallizes in regular octohedrons, and in rhomboidal dodecahedrons. Small octohedral crystals have been obtained by slowly cooling large masses of phosphorus. If a mixture of two parts of phosphorus and one of sulphur be melted under water, a compound is obtained, holding an excess of phosphorus in solution, and which is deposited in regular octohedral crystals on cooling. Its solution in sulphide of carbon, or in hot naphtha, when slowly evaporated in a current of carbonic acid gas, deposits regular dodecahedral crystals of considerable size.

SCHRÖTTER has carefully examined the boiling points of phosphorus under different pressures, and obtained the following results :—

Imperial inches.	Degrees.
4.72	329
6.81	338
8.03	356
10.40	392
13.30	408
14.10	424
15.40	439
20.20	446

When phosphorus is exposed to the air, even at ordinary temperatures, it undergoes a slow combustion, appears luminous, and diffuses white vapors, possessing a peculiar penetrating alliaceous smell. The phosphorous acid, PO_3 , hereby produced, attracting moisture from the air, condenses to a liquid, and taking an additional quantity of oxygen, is converted into a mixture of phosphorous and phosphoric acids, $\text{PO}_3 + \text{PO}_5$. This slow combustion is attended with a sensible evolution of heat, which gradually reaches the point at which phosphorus takes fire. It should therefore always be preserved under water. According to J. DAVY, the luminosity of phosphorus increases with the degree of rarefaction of the air, and is equally bright even in the vacuum of the air-pump. In air compressed to four atmospheres, phosphorus does not appear luminous till the temperature is raised. Nor does it shine below 32° degrees under the usual pressure, though at a few degrees higher it is distinctly perceptible. In oxygen gas, at the ordinary pressure, phosphorus does not shine unless heated to 80° , and may even be volatilized unaltered. The dilution of the oxygen with nitrogen, hydrogen, or carbonic acid causes it instantly to burst into the luminous condition.

The absorption of oxygen during the process of the slow combustion of phosphorus, may be proved by floating a small dish or watch-glass containing phosphorus on the surface of water, and covering with a bell glass. The oxygen gradually disappears, and water rises to fill the vacuum thus created. This oxidation of phosphorus in contact with the atmosphere, renders it a very useful agent for the determi-

nation of oxygen in the analysis of air, or other gaseous mixture. For this purpose, a ball of wetted phosphorus, fused upon the end of a wire, is introduced into the mixture of gases contained in a graduated tube, and standing over mercury. It is allowed to remain in contact with it as long as white fumes of phosphorous acid are visible round the ball. The vapors of phosphorous acid are ultimately absorbed by a ball of hydrate of potassa similarly introduced. The diminution in the measure of the gas shows the quantity of oxygen originally contained in the mixture.

The luminosity of phosphorus is so excellent a test of its presence, that if a drop of an extremely dilute solution of it in bisulphide of carbon be placed on a heated plate in the dark, the presence of one twelve-thousandth part is readily detected.

Owing to its powerful affinity for oxygen, phosphorus reduces the compounds of the noble metals, when placed in contact with their solutions, and quickly becomes covered with the reduced and precipitated metal. In contact with chlorine, bromine, and iodine, phosphorus inflames spontaneously, and without the aid of heat, producing respectively, chloride, bromide, and iodide of phosphorus. When heated in a copious supply of dry air, phosphorus burns with a brilliant white light, producing white fumes of anhydrous phosphoric acid, PO_5 , which, when condensed, much resembles snow.

Owing to the changes that take place in phosphorus on exposure to the air, it is necessary, to preserve it unchanged, to inclose it either in a gas free from oxygen, or in boiled distilled water. It is best preserved in stoppered bottles, completely filled with boiled water, and to exclude light, the bottle should be inclosed in a tin case, also filled with water.

Precaution.—In consequence of the great danger incurred in the handling of phosphorus, owing to its excessive inflammability, it is necessary, in all manipulations upon this substance, that a vessel, containing a mixture of chalk or magnesia and water, be placed in such a position as to be easily accessible to the operator. Phosphorus frequently, by simple contact with the warm hand, takes fire, melts, and continuing to burn, produces a painful and most troublesome sore, inflicting indeed, in some cases, frightful injuries. The danger is in a great measure prevented by immediately immersing the hand in the above mixture, as the earthy base neutralizes the strongly caustic acids formed during the combustion, and thus prevents further penetration. Phosphorus should always, if possible, be handled only under water, as the most gentle friction causes it to ignite.

AMORPHOUS MODIFICATIONS OF PHOSPHORUS.—Phosphorus, like sulphur, under the influence of apparently very trifling causes, assumes several allotropic conditions, some of which have been already alluded to.

White Phosphorus.—This modification is gradually produced whenever phosphorus under water is exposed to sunshine or ordinary daylight. The opaque crust is yellow at first, but afterwards turns white. Its specific gravity is 1.515. It smells like ordinary phosphorus, is luminous in the dark on exposure to the air, but turns red in daylight much more quickly than colorless

phosphorus. It retains its original appearance when dried over sulphuric acid, and sustains no diminution of weight. This variety of phosphorus was, until lately, considered to be a compound of phosphorus with water, or a hydrate of phosphorus, and the formula assigned to it by PELOUZE, was $P_2 H_2 O$. Had such a compound been proved to exist, it would have been the first exception to a well-known chemical law, that element combines only with element, and compound with compound. MARCHAND proved that the supposed compound was not a hydrate; for after having dried it over concentrated sulphuric acid, he found that it retained only 0.4 to 0.7 per cent. of water; thus showing that the water, instead of being in chemical combination, was present only hygroscopically, or in mere mechanical mixture. MULDER observing that it became red in aerated water—doubtless owing to the action of light—considered it to be a compound of phosphoric oxide and phosphide of hydrogen, and to be produced by the decomposition of water. ROSE proved it to be pure phosphorus, differing from the ordinary variety only in its state of aggregation. GMELIN, because it is not produced under water in the dark, accounts for its production on the supposition that phosphorus, under the influence of light, decomposes water, producing phosphoric oxide and phosphide of hydrogen, and that, in the dark, these two compounds are again resolved into water and finely divided phosphorus. The latter theory is probably the correct one, as it is a well-ascertained fact, that phosphorus under water, by the influence of light, does actually decompose water, and that the results of the decomposition are the two above-mentioned compounds— $7 P + 3 H_2 O = PH_3 + 3 P_2 O$.

Liquid Phosphorus.—Phosphorus, under certain conditions, after having been fused, retains the liquid form for some time after cooling, and, according to some chemists, even continues permanently in this condition. This variety of phosphorus has the appearance of a transparent oily liquid. It may be obtained by fusing ordinary phosphorus with an aqueous solution of hydrate of potassa. Under the solution it remains liquid for several weeks at ordinary temperatures, solidifies on being agitated, or by reducing the temperature to about 27° , and afterwards fuses at its ordinary melting point. Contact with a solid body, especially with solid phosphorus, also causes it to solidify. If poured upon bibulous paper, it becomes solid as soon as the adhering liquid has been absorbed by the paper, and with particular rapidity when touched with an iron wire. GROTHUS, by heating phosphorus with concentrated alcoholic solution of potassa, obtained it in the form of an oil which remained liquid on cooling, and when heated with water, evolved phosphide of hydrogen without acidifying the water. He, therefore, considered it to be a compound of phosphorus and hydrogen.

Black Phosphorus.—Another allotropic variety of phosphorus, distinguished by its black color, was discovered by THENARD. To produce it, phosphorus is melted at 150° , and while in a state of fusion, is poured quickly into very cold water. OSANN states that it may be obtained also by passing ozonized

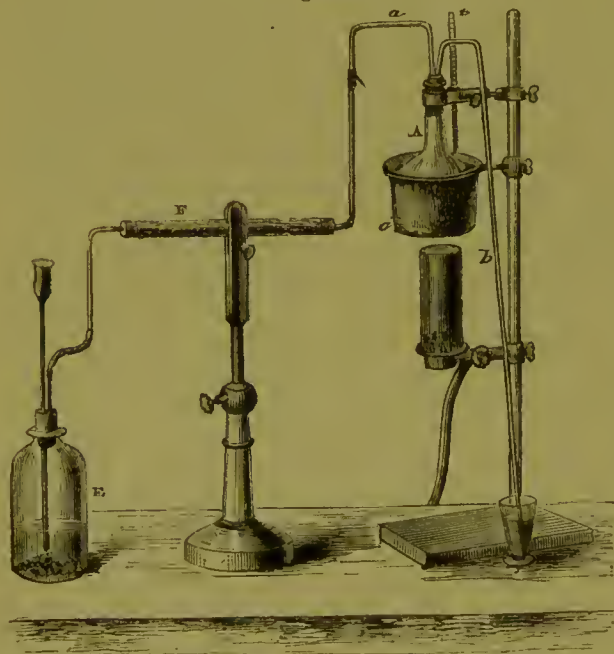
air over fragments of ordinary phosphorus for a considerable length of time; and also from the red oxide of phosphorus, procured by burning phosphorus fused under water with oxygen gas. The red oxide so obtained is boiled with concentrated solution of phosphoric acid. It thereby soon changes its color and bulk, and assumes a blackish-grey appearance. The boiling being continued, a black powder separates, whilst the mass becomes greyish-brown. OSANN, however, considered the peculiar color of this phosphorus to be owing to the presence of copper. The black variety of phosphorus is produced whenever fused phosphorus is suddenly cooled. The black color disappears, and it is reconverted into the ordinary condition by remelting, and slowly cooling.

RED PHOSPHORUS.—By far the most important allotropic modification of phosphorus is that known in commerce as the amorphous phosphorus of SÜRÖTTER, or *red phosphorus*. It was originally supposed to be an oxide, and its formation was attributed to the presence of moisture. BERZELIUS was the first who understood and described the precise nature of this substance. It was afterwards minutely investigated by SÜRÖTTER and others, who have shown in a variety of ways that the red substance is nothing but phosphorus in a peculiar state of aggregation. The latter chemist published in 1848 a description of it, and the method of procuring it. He placed perfectly pure colorless phosphorus, dried as completely as possible, in a glass tube, having a bulb in the centre, and passed pure and dry carbonic acid gas over it. The phosphorus was then gradually heated to 212° to drive off every trace of moisture, and the tube afterwards sealed hermetically, thus excluding every trace of oxygen. The phosphorus when exposed to light assumed a *red hue*, the depth of which increased in intensity the longer it was exposed to the light. The same results were obtained in hydrogen and nitrogen gas. Hence he concluded that the peculiar change of condition could not be ascribed to oxidation. SÜRÖTTER proved also that the alteration might be effected by heat. In a retort, to the neck of which a glass bulb was attached by fusion, he placed a quantity of dry phosphorus in the bulb as well as in the body of the retort. The extremity of the neck was connected with a glass tube thirty inches long, placed vertically, with its lower end dipped under mercury. The neck of the retort above the bulb was filled with chloride of calcium, and a thermometer inserted through the tubulure. The phosphorus in the bulb was then heated till inflamed, and all the oxygen contained in the retort was thus absorbed. The body of the retort was now heated to 212° , to expel adhering moisture, and then left to cool. Afterwards the phosphorus was gradually heated. At about 300° , sublimation commenced, but without change of color. At 439° , the phosphorus, after some time, assumed a carmine color; it likewise became more tenacious, and the color increased in intensity until perfect opacity was produced. This change was owing to the separation of a red powder, which settled to the bottom of the vessel, and rapidly increased in quantity till it extended throughout the whole mass. SÜRÖTTER afterwards obtained it in the coherent form, by exposure during several days in a

closed glass tube to an uninterrupted heat. This red phosphorus is obtained when even ordinary phosphorus is exposed to light, either under water or alcohol, or *in vacuo*, or in hydrogen, nitrogen, carbonic acid, carbide of hydrogen, or any gas in which it cannot oxidise; and also by exposure to heat between 419° and 480° . The change takes place, though slowly, at 419° ; but it is most rapid between 464° and 480° . It is accelerated also by the action of light. By heat alone, under diminished pressure, the conversion is slower, and does not appear to be produced when the pressure is reduced below $15\frac{1}{2}$ inches. In direct light, the metamorphosis is very active, but is perceptible also with a faint diffused light.

The following process for preparing this variety of phosphorus is extracted from MILLER'S comprehensive work. It is effected in the apparatus shown in Fig. 398. A quantity of dried common phosphorus is placed in the flask, A, to the neck of which a long narrow tube, *b*, bent downwards, is attached, the open end of which dips into a little mercury. The

Fig. 398.



removal of the air from the flask is accomplished by means of a current of carbonic acid evolved from the bottle, E, containing marble and hydrochloric acid; the gas is dried by passing it over chloride of calcium, contained in the tube, F. The flask being emptied of air, the tube is closed by fusion at the narrow portion, *a*, and the apparatus evolving carbonic acid is detached. The flask is then heated by means of an oil bath, *c*; the phosphorus melts readily; and by regulating the heat steadily between 450° and 460° , by means of a thermometer, *t*, and maintaining it thirty or forty hours, nearly the whole will be converted into the solid amorphous variety. When the metamorphosis appears to be complete, the apparatus is allowed to cool. Any unaltered phosphorus is separated by digestion in bisulphide of carbon, in which amorphous phosphorus is insoluble. The latter is afterwards collected on a filter, and washed with bisulphide of carbon as long as anything is removed from it, which

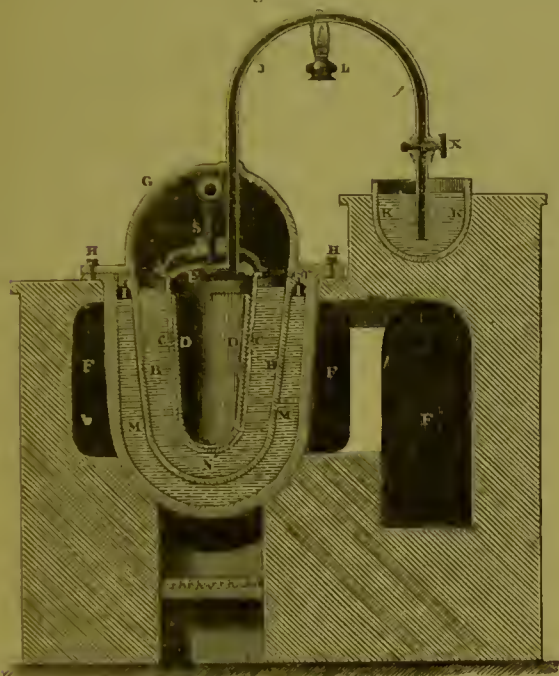
may be ascertained by evaporating a small portion in a watch-glass, when any dissolved phosphorus will remain behind.

The red powder obtained by the above process, if not quite free from ordinary phosphorus, inflames spontaneously, but if quite pure suffers no alteration by exposure to the air. To effect complete purification it should be boiled in solution of potassa of specific gravity 1.30, and then washed first with water slightly acidulated with nitric acid, and lastly with pure water. The color of this amorphous phosphorus is deeper the higher the temperature at which the transformation is effected; and in that of the finest specimens is more brilliant than vermilion. By heating the phosphorus more strongly during its preparation, the change may be effected much more rapidly; but the phosphorus then assumes the form of coherent flakes, which are difficult to purify, and are not easily detached from the vessel in which they are prepared. The process, however, requires great attention, and is not unattended with danger; as if the red phosphorus is heated to near 500° , the whole mass suddenly returns to the condition of ordinary phosphorus, with a copious disengagement of heat, succeeded by the sudden formation of a large volume of the vapor of phosphorus. Red phosphorus, therefore, appears to contain a large quantity of heat in the latent condition, which is liberated as it passes back into the ordinary vitreous state.

In 1848 a patent was granted to ARTHUR ALBRIGHT of Birmingham, for an invention communicated to him by SHRÖTTER of Vienna, for improvements in the manufacture of phosphorus, and in the apparatus to be used therein; and a Great Exhibition medal was awarded to him for the introduction of the prepared phosphorus as an article of commerce. By this process, red allotropic phosphorus is prepared on a considerable scale by Messrs. STURGE, also of Birmingham. A vertical section of the apparatus employed is represented in Fig. 399, and a view of it, as seen from above, in Fig. 400. A A is a cast-iron vessel set in brick-work, and having a fireplace underneath, with suitable flues, F F. From the inside of the flange of this vessel, a similar vessel, B B, of the same material, is suspended, and secured by means of the screw-pins, H. The space between the two vessels contains a metallic bath, composed of a mixture of equal parts of tin and lead. G is a cast-iron cover to the inner vessel, B, fitting the upper edge by means of a groove, and fastened to the outer vessel, A, by the screw-pins, I I I. A screw, S, passes through a three-armed iron holder, which is attached to a third movable iron vessel, C C, placed in a sand-bath, X. In the interior of this iron vessel, C C, another vessel of glass or porcelain, D D, is fitted, in which the phosphorus to be operated upon is placed. J is a curved pipe of iron or copper, passing freely through the cover, G, but screwed into the cover, E, and having an exit at the extremity into a detached vessel, K K. This contains water or mercury; if the latter be employed, it should be covered with water. The pipe, J, immersed in the mercury or water, serves as a safety valve, preventing the return of the atmospheric air into the inner vessel,

c c. The spirit lamp, L, is placed under the pipe, J, and is used, if necessary, to heat the curve, and prevent condensation of gaseous phosphorus, which, if allowed, would obstruct the passage. The stopcock, x, is used to prevent the ingress into c c of the contents of κ κ,

Fig. 399.



or of atmospheric air, and should be closed as soon as the operation is concluded, and before the apparatus in the furnace is allowed to become cool, or the vessel, κ κ, is removed. The cover, G, is not essentially necessary, its principal use being to prevent accidents. Between the end of the screw, s, and the cover, E, a small but strong concave disc or spring of steel is inserted, and so adjusted as to give a slight play to the

cover, E, in case of violent action arising in the interior, or the stopping up of the pipe, J, by condensed phosphorus. If the operation is conducted with proper attention, neither of these accidents is likely to occur.

Fig. 400.



The phosphorus to be converted into the amorphous state is to be previously melted and cooled under water, and afterwards dried as completely as possible. The mode of effecting the conversion is then as follows:—The phosphorus is deposited in the inner vessel, DD, and the covers, E and G, replaced. A fire is then kindled under the outer vessel, A A, and the temperature raised to such a degree as shall be sufficient to drive off the air and other gases that may be generated in the interior vessel; these will escape at the exit of the pipe, J, which dips into the mercury or water contained in the vessel, κ κ. When mercury is employed, it is desirable to cover it with a layer of water, so that any phosphorus which may distil over, and pass down the pipe,

J, may be covered thereby. The temperature is now to be gradually increased, until bubbles escape at the end of the pipe, J, which inflame spontaneously as they enter the air. When the gas has escaped freely for some time, the temperature may be further raised to 500°. To regulate the temperature, a thermometer is placed in the metallic bath before described. The length of time during which it is necessary to maintain the temperature, depends so much on accompanying circumstances that it can only be ascertained by experience. The heat should never be raised more than a few degrees above 500°. As soon as the operation is concluded, the vessel is allowed to become cool. The phosphorus is then taken out, to effect which it may be necessary to break the glass or porcelain vessel containing it. Should it be desirable to increase the pressure on the vessels, c c and D D, the vessel, κ κ, holding the mercury may be deepened, that it may contain a greater quantity, and thus a pressure of an atmosphere or even more may be gained. In this case, it will be necessary to remove the steel spring at the end of the screw, s, as soon as the steam and inflammable gases which arise in the first part of the process have ceased to issue from the pipe, J.

The phosphorus is then to be levigated under water, and drained therefrom by means of a bag or filter. If the operation has been successfully conducted, only very slight traces of unaltered phosphorus remain in the mass. The levigated phosphorus, still moist, should, in order to purify it, be spread thinly for convenient working on separate shallow trays of sheet-iron or lead. These trays may be so placed alongside each other as to receive the heat of steam, or of a hot water bath, or of chloride of calcium, or of sand, or of each consecutively in this order; but whichever be employed, the temperature must be gradually raised, and the phosphorus frequently stirred, until the disappearance of all luminous vapor shall show that the whole of the adhering ordinary phosphorus has become oxidised. The operator should have water at hand, to quench any fire that may arise before the whole mass was perfectly oxidised. The phosphorus is afterwards to be washed until the water running from it is perfectly free from all traces of acid.

The process of oxidation recommended by the inventor of the above-described apparatus, for the removal of unaltered phosphorus from the amorphous modification, is very unsatisfactory. A far better method, and one more quickly and more easily executed, is the application of an appropriate solvent, as bisulphide of carbon, oil of turpentine, or some other liquid hydrocarbon, by which the whole of the adhering unconverted phosphorus is readily and completely removed. This means of purification is also advantageous, inasmuch as the whole of the unaltered phosphorus obtained in solution may be recovered by simple distillation of the solvent, while in the process of oxidation the phosphorus, being converted into phosphorous and phosphoric acids, is lost, the acids being dissolved and removed by the subsequent washing.

Properties of Red Phosphorus.—Red amorphous phosphorus, in the state of powder, is lustreless, and destitute of crystalline structure. Its color varies from a scarlet to

a carmine red; sometimes also to a blackish-brown tint. When in the form of coherent masses, it is reddish-brown, exhibiting perfect metallic lustre and an iron-black fracture; sometimes the lumps are also of a bright scarlet color—usually, however, dark reddish-brown. It is brittle, very fragile, with a perfect conchoidal fracture. Its hardness is intermediate between calcareous spar and fluor spar; specific gravity at 60° is 2.14, exceeding that of ordinary phosphorus. Occasionally it has a porous appearance, resembling pumice-stone in structure, while some lumps are light enough to swim upon the surface of water. When heated in a liquid, it becomes darker in color, and after some time it acquires a deep violet. It is far less combustible than ordinary phosphorus, and is not luminous in the dark. When quite pure, it will bear a tolerably high temperature; but if it contains any unaltered phosphorus, is readily ignited by slight friction or percussion. It is not altered by exposure to the air at the ordinary temperature, but at 490° it takes fire, and if heated to from 490° to 500° in an inert gas, it passes into the state of ordinary phosphorus. Red phosphorus is insoluble in bisulphide of carbon, alcohol, ether, naphtha, chloride of phosphorus, and other solvents of ordinary phosphorus. In spirit of turpentine and other liquids which boil at a high temperature, it dissolves very sparingly during ebullition, but is deposited on cooling as ordinary phosphorus. It does not unite with sulphur until heated to 444°. It combines with chlorine with evolution of heat, but without any disengagement of light. The combination with bromine is attended with light. Concentrated sulphuric acid dissolves it when heated, with evolution of sulphurous acid, but is without action upon it in the cold. It is readily soluble in nitric acid with evolution of hyponitric acid, and formation of phosphoric acid. A boiling solution of potassa dissolves it, with disengagement of phosphide of hydrogen, not spontaneously inflammable, and it is at the same time converted into the black modification; indeed, according to SHRÖTTER, phosphorus always passes through the red state before conversion into the black modification. Red phosphorus decomposes many metallic oxides—for example, oxides of manganese, lead, silver, copper, mercury, especially if heated, sometimes with explosion. It deteriorates also when gently triturated with chlorate of potassa. If not perfectly freed from ordinary phosphorus, it ignites spontaneously when fractured, and also exhibits phosphorescence in the dark, and other properties of ordinary phosphorus. According to WÖHLER, red amorphous phosphorus may be rendered colorless and perfectly transparent, by fusing it in a concentrated solution of bichromate of potassa mixed with sulphuric acid. After this treatment it usually remains liquid after cooling, but solidifies instantly when touched by a solid body.

From a comparison of the properties of red allotropic phosphorus and the ordinary variety, it will be seen that the invention of SHRÖTTER is a great boon to those engaged in manufactories where phosphorus is largely used, and particularly to producers of instantaneous lights or lucifer matches, inasmuch as the red phosphorus is perfectly free from those pernicious

qualities which render the application of ordinary phosphorus to these purposes so destructive to health. In a commercial point of view it is also advantageous, as the red variety may be transported with perfect safety, while the carriage of ordinary phosphorus is attended with considerable trouble and risk, and consequent expense.

ESTIMATION.—Phosphorus is quantitatively determined as pyrophosphate of magnesia— $2\text{MgO}, \text{P}_2\text{O}_5$ —or as basic phosphate of sesquioxide of iron, being first converted into phosphoric acid by the action of boiling diluted nitric acid.

To estimate as pyrophosphate of magnesia, a weighed portion is taken, and treated with nitric acid until entirely dissolved. The solution is mixed with a considerable excess of ammonia; chloride of ammonium is then added; and lastly, sulphate of magnesia, as long as a precipitate continues to be formed. The mixture is allowed to stand twelve hours; the deposit of phosphate of magnesia and ammonia is then collected by filtration, and well washed with dilute solution of ammonia, dried, and heated to intense redness, to expel all traces of ammonia. Every one hundred parts of pyrophosphate are equal to 28.15 of phosphorus.

To determine as phosphate of sesquioxide of iron, a weighed portion of the phosphorus is taken, and oxidised as above by dilute nitric acid. To the solution of phosphoric acid thus obtained, is added a measured quantity of sesquichloride of iron, and the whole is precipitated by ammonia. The mixture is allowed to stand some time at a gentle heat, the precipitate afterwards separated by filtration, washed and exsiccated at a gentle heat, which is afterwards gradually increased to intense ignition. This precipitate is a basic phosphate of sesquioxide of iron. From its weight is deducted the quantity of sesquioxide corresponding to that of the sesquichloride of iron added, and the remainder expresses the quantity of phosphoric acid contained in the solution.

IMPURITIES.—Phosphorus is rarely adulterated, and the only impurities contained in it are those derived from the acid used in its preparation. DUMAS considers flexibility as a characteristic of good phosphorus. Occasionally arsenic, antimony, bismuth, and some other metals have been found in it. If the acid used contained arsenious acid, or an oxide of antimony, these are reduced in the process of manufacture of phosphorus, and are found in it in the metallic state. A solution of phosphorus in dilute nitric acid should give no precipitate with sulphide of hydrogen, and the precipitate procured by a barytic salt should be entirely soluble in excess of nitric acid, proving the absence of sulphur. If arsenic is present, the solution in nitric acid deposits a black precipitate of metallic arsenic when submitted to evaporation.

PHYSIOLOGICAL EFFECTS.—Phosphorus introduced into the stomach of animals acts as a caustic poison. According to ORFILA, the corrosion depends on the formation of phosphorous acid, by the oxidation of phosphorus in the pulmonary canal, and the action of this acid upon the tissue with which it comes in contact. It is very rarely used in medicine, though it has been strongly recommended in cases attended with

great prostration of the vital powers, and also in some chronic diseases of the nervous system. In small doses its operation is stimulant. It becomes absorbed, and communicates an alliaceous smell to the breath. After absorption, it excites the nervous, vascular, and secretory organs, raises the temperature of the skin, and increases the frequency of the pulse. Its general effect is that of a powerful sudorific and diuretic. In large doses it operates as an irritant poison, producing inflammation of the stomach and bowels, terminating in convulsions, insensibility, and death. It is usually administered in solution in ether, chloroform, and in oils. The antidotes to be resorted to in cases of poisoning are chalk or magnesia diffused in milk, together with mild demulcent liquids in large quantity.

STATISTICS.—Previous to the year 1845, the whole of the phosphorus consumed in this country was imported principally from the Continent of Europe. The amount of duty paid in 1844 showed a consumption of about one hundred and twenty-five hundred weight. Since that time it has been manufactured to a considerable extent in England. In 1853 the conjoint English and French product of phosphorus was estimated at one hundred and thirty-four tons. Manufactories of phosphorus are now to be found in Prussia, Baden, Bavaria, Austria, and Sardinia. At the Great Exhibition of 1851, samples were exhibited by COIGNIB and SON of Lyons, OTTO PAULI of Carlsruhe, and by SELOPIS of Turin and Brozzo, for which the former two received prize medals. The quantity fabricated in Europe probably exceeds three hundred tons annually. PAYEN estimated the annual consumption in the manufacture of lucifer matches in France at thirty tons. In England, the consumption in this branch of manufacture is far greater, one house, that of Messrs. DIXON, near Manchester, producing from six to nine millions of the finished article daily; this enormous number requiring about five pounds of phosphorus. In Austria and other parts of Germany, on account of the abundance and cheapness of timber and labor, this branch of industry is conducted on a still more extended scale, several manufactories making daily above six millions of matches.

PHOTOGRAPHY.—Of the various applications of chemistry to the arts, there is perhaps none more interesting than PHOTOGRAPHY—the art by which the images formed in the camera obscura are fixed upon various tablets, such as glass, paper, metallic plates, leather, *et cetera*; for when it is considered that by means of suitable lenses an image may be formed of any object, celestial or terrestrial, from which light proceeds, the applications of photography appear to be unlimited, and the art assumes an intellectual character, which raises it above those other arts of civilization that merely minister in some particular way to comfort or luxury.

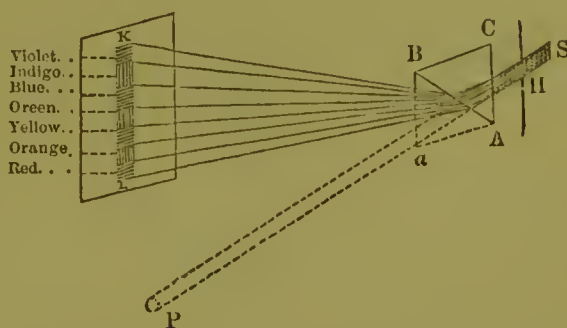
The word photography is derived from two Greek words signifying to *delineate by light*. It has been objected to this term, that the *luminous* rays are not those which effect the chemical changes that result in the production of an impression upon the sensitive tablet on which the image is received, but rather the violet rays of the spectrum; so that the word photography is a

misnomer. It was, however, hastily introduced, and having now become current in most modern languages, it is too late to alter it.

In point of fact, it is neither to the light nor to the heat of the solar rays that one is indebted for the beautiful results of photography, but to another mysterious power, a principle existing in combination with the light and heat of the sun, to which has been applied the appropriate name of *actinism*—a term derived from the Greek word for a *sunbeam*, and signifying merely the influence of the sun's rays, or *ray-power*, without involving the assumption of any theory on the subject.

To illustrate the composition and colored refraction of the sun's rays: suppose a beam of solar light is admitted into a darkened room through an aperture, *n*, in a window shutter, Fig. 401, and that it is made to pass through a prism of glass, *ABC*, with one of its angles downward, instead of being refracted altogether,

Fig. 401.



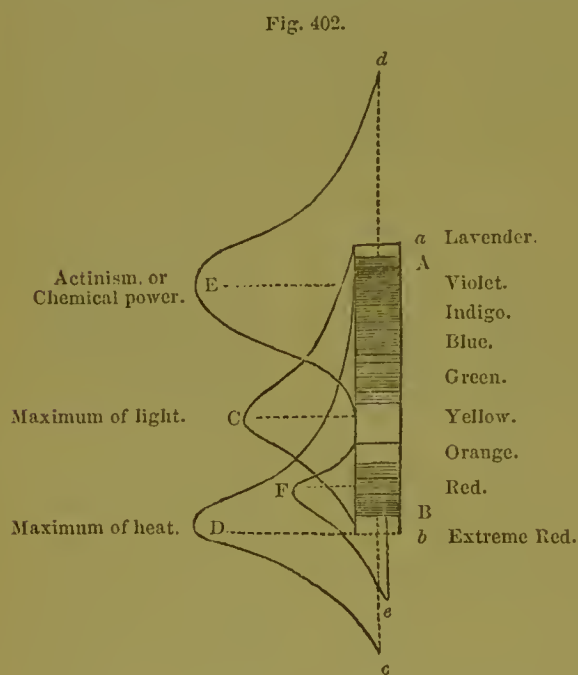
and appearing still as white light, which it does when the refracting surfaces are parallel—it is divided into several rays, and illuminates with different colors an oblong space of a white card, *K L*, placed to retain it. If one examines this oblong image with attention, it will be observed that it is distinguishable into seven colored bands, in the following order—violet, indigo, blue, green, yellow, orange, red. These are the seven *prismatic colors*; and the oblong image which they form is known, in scientific language, as the *solar* or *prismatic spectrum*.

The order of succession is invariable, and depends upon the unequal refrangibility of the different colored rays of which the composed white ray is made up. Thus the red ray deviates least from the direct path, *SP*; and the violet ray, most; and the intermediate rays have intermediate degrees of refrangibility—the orange is thrown further from the direct path than the red, and the indigo deviates less than the violet; and hence one speaks of the violet end as the most refrangible, and the red as the least refrangible end of the spectrum.

It is important to remark, however, that below the ordinary visible red, or least refrangible ray, another ray of a deeper red, distinguished as the *extreme red*, or *crimson ray*, may be detected by examining the prismatic spectrum through a deep blue glass; and by throwing the spectrum upon a piece of yellow paper, another ray appears at the violet extremity, named, by Sir JOHN HERSCHEL, the *lavender ray*.

The spectrum exhibits, therefore, when fully analyzed,

a wonderful variety of properties, of which the diagram, Fig. 402, will give a sufficient idea. In this diagram, the shaded portion represents the colors as they occur in the decomposed solar beam; the space included between *a* and *n* exhibits the Newtonian spectrum, and *a* and *b* are the rays which Sir JOHN HERSCHEL has added, thus increasing the number of the different perceptible colors from seven to nine; but all of which, as Sir DAVID BREWSTER has shown, are really reducible to three primary colors—red, yellow, and blue. The curved lines in the engraving represent the relative amount of *actinism*, *light*, and *heat*, in different parts of the spectrum. It will be observed that the actinism is



greatest at E, and ceases at *d* and *e* towards either extremity. At the point of greatest light, C, which is in the yellow ray, there is absolutely no actinic or photographic influence. At F, however, near the point of greatest heat, D, the actinic or chemical influence is sensibly felt; but this is ascribed by M. CLAUDET to the yellow rays being not merely passive or inert as regards actinic power, but having a positive destructive influence on any effects produced by the actinic rays.

Whatever be in this, it has been positively ascertained by experiment, that the *yellow*, which is the most luminous ray, has only a small heating power, while the greatest actinic or photographic power exists at that point of the spectrum where the light and heat are least sensible, and even, like the heat at the other extremity, extends a considerable distance beyond the spectrum entirely, producing effects on photographic paper where the rays of the sun are absolutely not visible.

This analysis of the refracted rays of a pencil of white light explains why a much longer exposure is required to insure a photographic image at the equator, than in Northern or Southern latitudes; the yellow rays being more abundant in the former region than in the latter, and actinism being wanting in proportion; in the latter it is *vice versa*.

HISTORICAL NOTICE.—The dawn of photography is intimately connected with researches on light. For a long time the question, whether light possessed any chemical properties, was discussed by a numerous body of scientific men. SCHLEIER was the first to draw attention to the subject of the rays of the sun possessing properties able to effect chemical changes, more especially upon silver salts, and showed the comparative power of the different rays to darken them. In this department he was followed by SENLEBER, COUNT RUMFORD, and RITTER, who was the first to notice that solar beams, not possessing luminosity, but having a remarkable effect in inducing chemical metamorphoses, existed in sunlight. Between 1801, the period of RITTER's researches, very little was done bearing upon the origin of photography, till the celebrated JOSIAH WEDGEWOOD, in 1802, published his method of producing sun pictures, by coating white paper or enamelled leather with a solution of nitrate of silver, and exposing the coated surface to the light of the sun under a painting on glass. Although he anticipated the advantages which would accrue from the art, he could not partake of them to the extent he deserved, owing to the means of fixing the impression being then unknown to him, notwithstanding the fact of Sir HUMPHREY DAVY being engaged with him in the inquiry. It appears that NIEPCE was the first who partially succeeded in fixing the image produced in the camera obscura; but this was not till 1827, long after the disclosures of WEDGEWOOD, and after many years' investigation. Previous to this period, DAGUERRE was likewise occupied with the subject, but was unsuccessful. In 1829 he entered into an agreement with NIEPCE to pursue their several researches on this subject for mutual advantage. At the period of the compact the latter published his method, which he called *heliography*. It consisted in coating a highly polished tablet of plated silver with a mixture of petroleum and essential oil of lavender, reduced to the consistency of thin varnish. After drying at a gentle heat, the prepared plate was exposed in the camera to the image thrown upon it, and after due time the latent impression was rendered visible by disengaging the unaffected parts. This was executed with a solvent composed of one part of oil of lavender, and ten of ordinary white petroleum or spirit of tar. On pouring this liquid over the plate, the impression began gradually to show itself; when sufficiently defined the plate was removed, the dissolving liquid allowed to drain off, and the operation terminated by careful washing. At this period they were anxiously seeking for a substitute for the varnish, and had recourse to alkaline sulphides and iodine for blackening the plates to form a ground for the picture; but the results were not as satisfactory even as the varnish coating, although the latter proved subsequently to be the most eligible in the hands of DAGUERRE. The heliographic method of NIEPCE was a very slow and uncertain process, requiring several hours' exposure in a strong light before a tolerably defined impression was made. DAGUERRE improved the process by using the resin of the essential oil of lavender dissolved in alcohol for the basis, and the vapor of petroleum, which

had not the effect of removing most of the varnish to the injury of the picture, as was the case in the other. From this period till that of NIEPCE's death the subject was actively prosecuted on both sides; but it would appear that the latter *savant* had lost faith in the efficacy of coating the plates with a metallic film, such as sulphide or iodide of silver; whilst DAGUERRE seemed as much impressed with these, or similar ones, being the true media for taking impressions. After the death of NIEPCE in 1833, the compact was renewed between DAGUERRE and the son, ISIDORE NIEPCE, and the research was as unflaggingly pursued as before till 1839, when DAGUERRE was fortunate enough to discover the beautiful process which is now so well known under his name. It is almost needless to say, that upon the publication of the process, communicated to the Academy at Paris, the beauty of the gradations of light and shade, and the extreme delicacy and truthfulness of the pictures, took both the whole of the old and new world by surprise; and after the French Government had secured to DAGUERRE and NIEPCE a pension adequate to the importance of the discovery, and gave the process to the world, its practice became universal.

Whilst the French were diligently occupied in bringing the process of producing pictures on metallic plates to perfection, in England the subject was silently pursued by Mr. HENRY FOX TALBOT. His experiments were undertaken in 1834, with the view of rendering the image produced in the camera obscura permanent in the sun; these were prosecuted with varied success till 1839, when a paper was read by him to the Royal Society, on the thirty-first of January of that year, entitled—*Some Account of the Art of Photogenic Drawing; or, the Process by which Natural Objects may be made to delineate themselves without the aid of the Artist's Pencil*. This was the first account of this process—since called *talbotype*—methodized to the production of pictures. In February of the same year a fuller account of the preparation of the paper, and the method of fixing the picture, was communicated to the same body. TALBOT's pictures were produced on paper prepared for the purpose; and though less delicate in detail, in consequence of the inequality of the basis, than daguerreotypes, still they could be viewed with equal effect in any position, and were consequently free from the defect experienced in looking at the latter.

From this it will be evident that the British philosopher pursued his investigation independently of the French laborers in the same field; and arriving at results in a measure as satisfactory as those of DAGUERRE, he contributed, as HUNT remarks, equally with the latter most important services to *science*, in producing an instrument by which the mysterious phenomena of light could be satisfactorily investigated; and to *art*, by giving her votaries tablets upon which Nature impresses herself in all her delicacy and decision, in all her softness and grandeur, and in all her richness of tone and breadth of effect.

The fixing agent first used by TALBOT was a concentrated solution of chloride of sodium, which had the effect of dissolving the unaltered chloride of silver.

Iodide of potassium was employed for a similar purpose; but these do not give results as satisfactory as the hyposulphite of soda introduced by Sir J. HERSCHELL. Other improvements by the latter philosopher have also to be recorded, which, though not so important as the one just referred to, contribute, nevertheless, to the perfection of the art. This is particularly the case with his researches on the solar spectrum, the results of which have been already given, and by which he has laid the foundation of the principles of actinism, and brought it to its present comprehensive state.

HERSCHEL was the first to recommend the practice of saturating the saline washes used to prepare the paper with chloride of silver, and the employment of a double wash of nitrate of silver to be used in succession, alternated with drying the paper, with the view of doing away with the whitish spots so frequently seen in the pictures of TALBOT at the time; he also noticed—as likewise ROBERT HUNT—a method of fixing the impression formed in the camera with chloride of mercury, and, at the same time, rendering the paper to all appearance fit for the ordinary uses of writing and the like; whilst nothing was required to develop the picture but simply washing with hyposulphite of soda.

Another very efficient discovery of TALBOT's may be here recorded—namely, the property of gallic acid in rendering the prepared paper so sensible as to be capable of receiving impressions by instantaneous exposure, owing to the gallic acid of the ingredients continuing and developing the effect of the sun's rays. This agent was ultimately superseded by pyrogallie acid, introduced by ARCHER, the reducing or developing action of which is much greater than that of the gallic compound. Various methods for rendering paper sensitive to the reception of solar influence have been published, to dwell upon which would take up too much space. All, however, have their particular advantages, based upon the judicious application of the usual compounds, so as to produce a more even and more perfect coating with the silver salt.

Subsequent to the production of photographs on paper with considerable accuracy, glass was adopted for the basis of the picture; but as the sensitive media could not be made to adhere to this body alone, it was necessary to employ as an adjunct some adhesive matter. The first trials were with albumen—introduced by NIEPCE St. VICTOR in 1848—and gelatin, laid in a thin stratum upon the clean surface of the glass. Iodide of potassium or alkaline chlorides were mixed with the adhesive composition; and after partial drying, the surfaces were exposed to solutions of nitrate of silver, when a sensitive coating formed on the film on which the picture was impressed. Generally, the pictures obtained on albumenized or gelatinized glass, owing to the even and close texture of the coating material, had many qualities superior to those produced upon paper, excepting where the practice of employing the latter waxed was followed. It was soon after the adoption of these materials by photographers, that ARCHER introduced pyrogallie acid, and soon after collodion, than which no other material is now more

extensively used. With the exception of modifications introduced from time to time to render the collodion film more sensitive, or to propagate the impression of the rays of light, and thus shorten the period of exposure, very little has been done within the last few years beyond rendering the art more general both in practice and application. Xyloidin, a compound prepared from starch with nitric acid, and tintured with iodine, was introduced a few years ago; but its use is not so extensive as that of collodion, notwithstanding its repute for being a more compact basis for the picture, and more capable of receiving the pictorial impression. The particulars of these methods will be detailed further on when describing the practice of photography. Besides the various progressive steps alluded to, there are a few others which tend to extend its usefulness, and deserve a short notice.

These are the methods for impressing colored pictures upon the prepared surface, and of engraving the photographic impression without the aid either of the artist's graver or pencil.

The latter, which might be called photogalvanography, is not recent, but almost as old as the first bituminous impressions of M. NIEPCE, whose finished pictures required but the application of the etching liquid to convert them into engravings. The system of procedure had been considerably improved by several others, more especially by NIEPCE the younger, LEREBOURS, and LEMERCIER, the latter applying it to lithographic printing. Dr. DORME of Paris endeavored to obtain engravings from daguerreotype plates by chemical agency, and partially succeeded. His method was to attack the plate with nitric acid before the gilding of the picture, when all the parts whereon the silver was reduced became more or less corroded according to the depth of shade. As nitric acid happened to be the agent used, it could not be always confined to the parts where its action should be manifested, and, therefore, the results were precarious. GROVE published a method for engraving the daguerrean image by voltaic agency in 1842; in this operation, the agent was chlorine liberated from hydrochloric acid, in which the picture, attached to the positive pole of the battery, was immersed. This method, though superior to its antecedents, was not all that was desired. A patent was granted in 1844 to FIZEAU and CLAUDET for engraving photographic impressions. Here hydrochloric acid, liberated from a mixture of chloride of sodium and nitrate of potassa, to which a little nitric acid had been added, was the etching medium, and ammonia and a hot concentrated solution of caustic potassa the auxiliaries to it in bringing the process to perfection—the former having the effect of removing the chloride of silver, and the latter protecting the surface coated with the mercury from the corroding action of the acid. When sufficiently deepened the plate was washed and dried, smeared with printers' ink, dried, cleaned, and the unetched parts gilded, after which the remaining parts could be deepened at will by first removing the ink. Another method discovered by H. F. TALBOT, and published by him in May, 1853, seemed to be most satisfactory. It consisted in coating a well-polished steel plate with a mixed gelatin

impregnated with a strong solution of bichromate of potassa; and, when dried, exposing this plate to the rays of light impinged from the illuminated subject in the camera; or, better, to the sun's rays, whilst a positive photographic picture had been laid upon it. As in the case of NIEPCE's bituminous method, so in this—the influence of the light rendered the parts on which it fell insoluble, so that on subsequently washing in water the gelatin and bichromate solution were removed from the other parts, leaving a raised facsimile of the picture, the lights being represented by the bare metal, and the shades—corresponding to the lights in the original—by the altered gelatin. On pouring bichloride of platinum upon the washed surface, the plate became readily etched on the parts from which the gelatin was removed. When the action has been sufficiently continued, it is arrested by washing with a sponge, which removes the gelatin, and drying. The plate now exhibits a delicate etching of the picture on the steel plate, in which the raised surface corresponds to the light and half tones of the original design. PRETSCH of Vienna published a method for effecting the same purpose; it has much in common with TALBOT's, but instead of washing off the coating of gelatin, as directed by the latter, it is merely soaked in water, to swell the unaltered gelatin, and give the appearance of an engraved wood-block to the figure. An impression of the figure is then taken with a soft material in the way of a mould, and the latter is rendered a conductor of electricity, and copper is deposited upon it to any desired extent. In this way a true impression is taken of the photograph in copper, and may be multiplied at pleasure. Latterly, PORTEVIN of Paris has used the same materials as TALBOT, and applied them to lithographic stone, and the results appear to be very satisfactory. Notwithstanding these several steps towards improvement, much still remains to be effected, both as to investigation and discovery, to give the art the utility which it is calculated to possess.

In color printing, or chromophotography, also, efforts have been made to impress the tints of the object upon the picture by chemical agency, but the results have not been as successful in this department as those just detailed of photogalvanography; still, sufficient indications have been given to show that the subject is feasible of attainment. In chromophotography, or heliochromy, as the process was called in France, BECQUEREL in 1854 and previously, showed that colors could be impressed on the picture at the instant of its formation, by employing the violet chloride of silver—a compound in which more or less of a basic chloride exists—for taking the picture. To give the subject more definition, he coated the silver plates by means of chlorine liberated from hydrochloric acid by voltaic agency, and in which solution the tablet was immersed, attached to the positive pole of the battery. As it was found that the shades were much altered by the thickness of the coating of the violet chloride on the plate, he introduced a voltmeter of water in the circuit, to measure from the volume of hydrogen disengaged the quantity of chlorine set free, and by this means he was able to determine the quantity of gas that passed over a given extent of the plate. When a plate so prepared was

exposed in the camera to the solar light of the spectrum, all the chief colors were produced, beginning with the yellow and orange, and extending to the red and violet, thus leaving a colored picture. BECQUEREL observed that a temperature of 212° to 302° , applied to the plate before exposing it to the spectrum, or a heat of 97° kept up for two or three days, modified the strength of the colors, though giving good yellow and green impressions. As these hues could not be fixed so as to resist the effect of diffuse light, they were looked upon more as a scientific curiosity. NIEPCE ST. VICTOR being led to infer a relationship between the color which many bodies communicate to flame, and that which light develops in a plate of silver coated as above, tried the effects of silver plates excited in chlorine water impregnated with various salts, such as chloride of strontium and the like, and placed the plate in the camera for the reception of the rays from colored bodies, when the image became impressed with the natural tints of the subject. Thus, an orange was obtained by the use of chloride of calcium, yellow by chloride of sodium or chlorine, red with chloride of strontium, green with boracic acid and chloride of nickel, and so on, employing for any particular shade a substance which similarly colors the alcoholic flame, or that of the blowpipe.

Mr. HILL of the United States had been engaged upon the same subject, and gave the public to infer that he had arrived at satisfactory results in obtaining colored photographs as early as 1850, by means of some chance composition of a nondescript nature; but though he has given details of the pictures he produced by this means, the Editor is unable to find any description of the method or substances which he employed. It is certain, however, that no sure means of impressing the hues of the natural bodies upon the daguerreotype or photograph have been yet arrived at; and notwithstanding the instances referred to, that the discovery of the process still remains a desideratum in the science and art of photography.

The art of photography is dependent partly on optics, and partly on chemistry. It is the business of the optician to provide a suitable camera in which the photographic tablet may be placed, and the image formed by the lens thrown upon it. It is the business of the chemist to prepare the sensitive tablet in a suitable manner to receive that image.

THE OPTICS OF PHOTOGRAPHY.—The simplest form of camera obscura is a dark box, having a small orifice in the centre of one end, and a focusing screen of ground glass at the other. On throwing a black cloth over the head and camera, and looking at the focusing screen, an inverted image is seen of the objects towards which the opening of the camera is presented. When the hole is large, this image is bright but indistinct; by reducing its size, the image becomes more distinct, but fainter. The brightness and size of the pictured objects depend upon the distance of the focusing screen from the hole; and the smaller that distance may be, the smaller are the objects and the brighter the picture. The shape of the aperture does not determine that of the picture or the outline of the objects, a triangular hole giving the

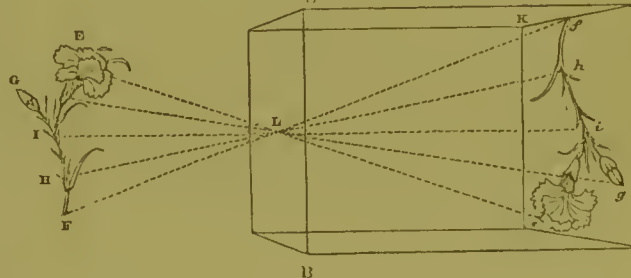
same image as a round one. The image formed in this simple camera, although more or less indistinct, is absolutely free from distortion, and the rules of plane perspective are strictly fulfilled.

To understand the principles on which the cameras are constructed, it must be remembered that every visible object of which an image can be formed by a lens, is supposed in optics to consist of an assemblage of luminous points, from each of which rays of light proceed in all directions, but without interfering with each other; and an assemblage of rays proceeding from any single point is called a *pencil*. A bright object, therefore, emits a pencil of light from each of the bright points composing it. Thus if *A C*—Fig. 403—be a piece of brass wire, the several points of it, *A, B, C*, emit each a pencil of light—not a single ray—and these pencils do not interfere with each other. To illustrate this further, let *E F*—Fig. 404—be the object, *B C* the camera, *L* the hole, and *K D* the focusing screen; then a pencil of light proceeding from *E* passes through the hole *L*, and the rays continue to diverge until they reach the focusing screen at *e*, at which point a spot of light is produced of the same shape as the hole at *L*, but somewhat larger than it, and of the same color as the point *E* of the object. Similarly the points *F, G, H, I, et cetera*, emit pencils which after passing through the hole illu-

Fig. 403.



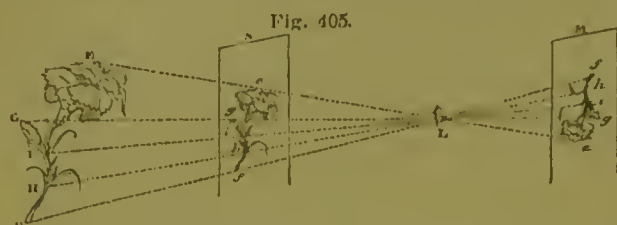
Fig. 404.



mine the spots at *f, g, h, i, et cetera*, and in this way an indistinct inverted image of the object is formed. The size and shape of the image do not depend upon the opening, because the luminous points of the object being infinite in number, and in close juxtaposition, the spots of light which compose the image, although individually of the same shape as the holes, glide one into the other, and form a continuous outline, in which all trace of the form of any particular spot is destroyed.

To show that the image upon the focusing screen is a correct perspective view of the object, the following illustration is submitted:—Suppose that *L*—Fig. 405—is the eye of a spectator, which is considered to be a mathematical point, and that straight lines, called *visual rays*, are drawn from *L* to the several points of the object *E F*; these straight lines constitute the edges of a system of pyramids, of which *L* is the common vertex, and if these are cut by any vertical plane at *N* between *L* and the object, the section is a plane perspective view. This is the fundamental definition of a plane perspective view. Now, let it be supposed that the visual rays are produced through *L*, so as to

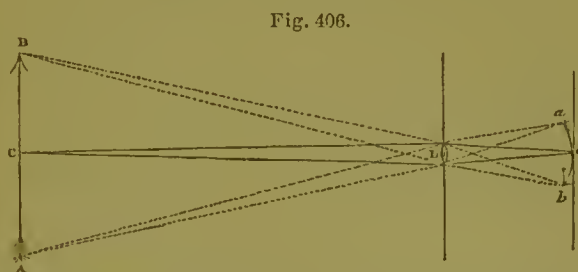
form another system of pyramids on the opposite side of it; it is evident that if this second system be cut by a plane at *M* parallel to that at *N*, and at an equal distance



from *L*, the inverted image thus formed would be an exactly equal and similar geometrical figure to the image at *N*, and the two figures would coincide if one were laid against the other. But the image at *M*, is that which would be formed by a camera having a hole at *L*, and a focusing screen at *M*; so that this simple camera gives a correct perspective view of the object as seen from the aperture, and depicted upon a plane surface as far in front of the hole as the focusing screen behind it.

The great defect of the image produced in the simple camera is, its indistinctness, because the pencils have no foci or point of concurrence of the rays. In order to remedy this evil convex lenses, or convex combinations of lenses, are introduced and placed at *L*.

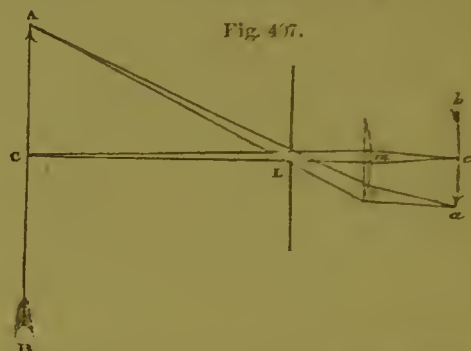
The simplest form of lenticular camera is that in which a very small convex lens is placed at *L*—Fig. 406. A direct pencil diverging from a point, *c*, of an object is then, after refraction through the lens, brought to a focus at *c*, where a distinct image is formed; but the



oblique pencils from points *A*, *B*, are brought approximately to foci at points *a*, *b*, upon a circular arc, of which *L* is the centre, and *Lc* the radius, and the rays after passing through the points, *a*, *b*, again diverge and produce round spots or discs of light upon the screen, instead of a sharp focus as at *c*; the true image of the object being curved, as shown in the figure. A small single lens, therefore, gives so much curvature of the image as to render its margin very indistinct compared with the centre. It will be observed, however, that the image formed by a small single lens is free from distortion, because the axes of the pencils do not suffer deviation by passing through it.

In order to increase the radius of curvature of the image, the following plan has been adopted in the lenses used by photographers for taking views; in these the light enters through a small aperture, and the time of exposure is a matter of less consequence than obtaining a picture uniformly sharp to the edges. Instead of placing a small lens at *L*, a large one is fixed at some distance behind *L*, as in Fig. 407. A central pencil from *C* is refracted through the centre, *m*, of this lens,

and an oblique one from *A*, after passing through the hole at *L*, is refracted near its circumference at *n*. This renders the image much flatter; because the distance, *na*, which is equal to the focal length, *mc*, of the lens, is measured from *n* and not from *m*, as in the case of a single lens placed at *L*. But this arrangement is open to the very serious objection, that the image is greatly distorted, in consequence of the axes of the oblique pencils being bent out of their course by refraction through the circumference of the lens, which acts as a prism in causing rays to deviate from its edges, and, therefore the marginal parts of the image are too small for the central; besides, all straight lines in the image which do not pass through the centre are curved inwards at their extre-



mities; so that in this form of view-lens, flatness of field is gained at the sacrifice of true perspective.

The form of this lens is meniscus, or concavo-convex, the concave side being turned towards the objects; and the radius of curvature of the image is equal to the focal length of the lens, plus the radius of its convex surface; it is, therefore, longer by the latter quantity than the radius of curvature of the image formed by a small single lens without a diaphragm in front.

All photographic lenses require to be achromatized, or so constructed as to refract the different colors equally, in such a way that the yellow and violet foci may coincide; because the yellow rays produce the *visible image*, while all the rays of the spectrum which lie between the green and the extreme lavender produce more or less chemical effect upon the sensitive photographic tablet. The common view-lens is an achromatic meniscus, and it may be achromatized in two different ways, one of which consists in placing a double

Fig. 408.

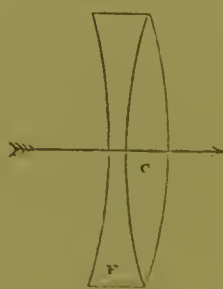
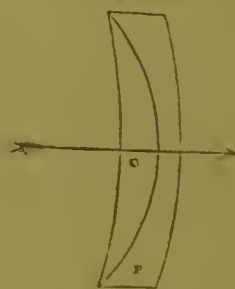


Fig. 409.

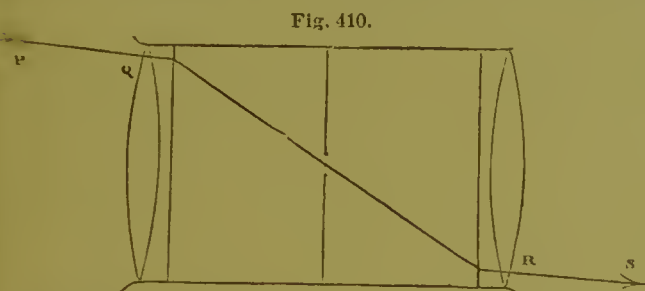


concave lens of flint-glass before and in contact with a double convex lens of crown-glass, as shown in Fig. 408; and the other, in placing a concavo-convex lens of crown-glass before and in contact with a concavo-convex lens of flint-glass, as shown in Fig. 409. The

effect of these combinations arises from the circumstance, that flint-glass and crown-glass possess very different powers of *dispersing* or of separating the rays of light.

In the preceding Figs., c denotes crown, F flint-glass. Both forms have equal radii of the front and back surfaces, equal focal lengths, equal curvature of the image, and an equal distortion; but the plan shown in Fig. 409 is the best, because there is rather less spherical aberration. Even this is very bad, and should be superseded by the view-lens, which has recently been invented by Professor PETZVAL, and which will be described presently.

The best form of *view-lens* for giving pictures entirely free from distortion is a combination of two achromatic plano-convex lenses, with the convex sides outwards, and a small stop midway between them, as shown in Fig. 410. If a ray, P Q, be refracted



through this combination in such a way that its course between the lenses passes through the centre of the stop, it is evident, from the symmetry of the figure, that the emergent ray, R S, will be parallel to P Q; from which it follows that the axes of pencils refracted through this combination do not suffer deviation, and therefore there is no distortion in the image. The curvature of the image is, however, greater than with the single view-lens, and the central definition, when the diaphragm is removed, not quite so good as that of the *portrait-lens* to be described presently.

The best view-lens for combining tolerable freedom from distortion, with flatness of field and perfection of focus—that is to say, the most generally useful view-lens is that of Professor PETZVAL of Vienna, and commonly called the *orthoscopic lens*, from the fact that the straight lines of objects are not curved in the image. Its construction is shown in Fig. 411. The front lens is achromatic and convexo-concave; and the back lens achromatic, and composed of two,



which only touch at the edges. The inner one—that is, the one next to the front lens—is of crown-glass and double concave, with the deepest concavity next to the meniscus; the outer one is a meniscus of flint-glass. The front lens of the combination is convex, and brings rays to a focus; the back lens is concave, and scatters them. In order to improve the definition, and bring objects at different distances into good focus, a stop is placed immediately behind the back

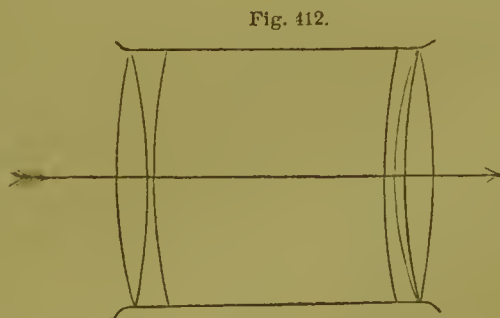
lens. The distance between the front and back lenses of the combination is about equal to half the diameter of the front lens, and the diameter of the back lens is about two-thirds that of the front one. In this combination the oblique pencils pass near the circumference of the front, and through the centre of the back lens; they are therefore lengthened, and the consequence is the production of a very flat field. A small amount of distortion is produced by this instrument, which causes straight lines not passing through the centre of the picture to be curved *outwards* at their extremities, and the objects at the margin of the field are rendered proportionally larger than those in the centre; but these defects exist to a much smaller extent than those of an opposite kind in the single view-lens.

There are, therefore, three different view-lenses used by photographers, namely—the single view-lens, with a stop in front, which gives a flat field, but great distortion; the symmetrical double combination, which gives an image entirely free from distortion, but having considerable curvature; and the orthoscopic combination of PETZVAL, which gives a tolerably flat field, and the image *nearly* free from distortion. The second lens is the best when a sufficiently small stop can be used to obtain good marginal definition. In other cases the orthoscopic lens is the best, and the single view-lens the worst.

The view-lens includes an angle of from 35° to 40° . It cannot be used for portraits in a glass room, because it would require too long an exposure.

The *portrait-lens* commonly used is that which was invented by Professor PETZVAL about seventeen years ago. In this combination everything is sacrificed to getting a large central pencil free from spherical and chromatic aberration. The curvature of the image is considerable, and the angular field of view rarely exceeds 20° . Its only merit is quickness of action, which is absolutely required in photographic portraiture. As soon, however, as more rapid processes are discovered, the portrait-lens, with its large aperture and many unavoidable defects, may be given up.

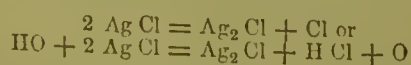
The construction of the portrait combination of PETZVAL is shown in Fig. 412. The front lens is



achromatic and convexo-concave, the lenses being in contact. The back lens is achromatic, and formed of two lenses separated by a small interval; the inner one is of flint-glass, and convexo-concave, the outer one of crown-glass, and double convex, with the flatter side outwards. The focal lengths of the two compound lenses are nearly equal, the front lens having the longer

focus, and both are convex lenses. The combined focal length of the instrument, measured from the back one, is from three to four times the diameter of the front lens. Sometimes, when the light is strong, or it is required to take objects out of doors, a stop is used. This should be inserted between the lenses, and the proper place for it must be determined by trial. If placed too near the front lens the image of a perpendicular straight line brought to the margin of the focusing screen is bent *inwards* at the extremities, and if placed too near to the back lens, *outwards*; there is an intermediate point where the image is perfectly straight, and that is the proper place for the stop. In mounting lenses care should be taken to exclude stray light, and to prevent reflections from the inside of the tube, and the outside edge of the lenses by blackening the interior.

THE CHEMISTRY OF PHOTOGRAPHY.—In this department of the art, the principle involved is the production of a saline surface which is capable of being modified by the actinic or chemical rays in light, the development of this action by chemical means, and finally its fixation, by removing all matter which is capable of further change by the agency that produces the picture. The substances which are pre-eminently employed in this art are the various salts of silver, more especially the chloride, iodide, and bromide of this metal. Besides these, there are other compounds which are capable of being acted upon in a similar manner, and consequently give, under proper treatment, impressions of objects; such, for instance, are compounds of gold, uranium, chromium, and other easily reducible substances. It is well known to every chemical student that a silver salt, such as the chloride, iodide, bromide, phosphate, and the like, when freshly precipitated and presented to the sun's rays, rapidly assumes a purplish hue, and finally turns black. So, also, in regard to compounds of gold, uranium, or chromium, an effect is observed when these are exposed in very thin layers, that shows a chemical action has taken place. In all these cases where diffuse light makes an impression, the effect is due either to a reduction of the salt to one of a more basic nature, or to the isolation of the metal from the salifiable body. For example, supposing a surface coated with a thin layer of chloride of silver be exposed to the light of the sun for a short time, the resulting darkening of the pure white of the salt is due to an abstraction of part of the chlorine from it; if its exposure be continued the change gradually progresses, till finally the compound will contain no chlorine, or at best but a very small portion. To illustrate this, if the chloride of silver be represented by AgCl , the effect of the chemical action of the actinism or chemical principle in light may be expressed by the formula—



that is, two equivalents of the silver salt will evolve one equivalent of their chlorine when water is absent, or one of oxygen when water is present. By continuing the reducing effect of the light, the chlorine ultimately is entirely separated, and only finely-divided metal remains. The latter change is, however, rarely

effected in the ordinary practice of the photographer. As with silver, so with gold and the other substances alluded to; they all lose a portion of their salifying element, and thus acquire a composition different from what they originally possessed, becoming by such metamorphoses more permanent under radiant influences.

In photographic practice, the action of the light is propagated by other chemical compounds, generally those which have a great affinity for oxygen, and by assimilating which they pass into a higher state of oxidation. Such are the various preparations of the protoxide of iron, protosalts of tin, and formic and other organic acids that are capable of assimilating oxygen from metallic salts. Hence the practice of *developing* the image incipiently formed by the light with a protosalt of iron, or any of the other compounds just alluded to. Besides these, another process of a chemical nature is required to give permanency to the impression produced by the combined agency—by the impinged rays and the reducing agent—and which has for its object the removal of the sensitive salt from the parts which form the lights in the positive and the shadows in the negative pictures, presently to be described in the practical details of the art. The agents used for this purpose are water, hyposulphite of soda, $\text{NaO S}_2\text{O}_3$, ammonia, cyanide of potassium, and a few other compounds capable of dissolving the metallic combinations employed for the basis of the picture. After bringing these chemical processes to bear upon the production of a photographic picture, nothing further is necessary beyond the few simple operations of drying and mounting.

The chemical principles that govern the art will be more fully enlarged upon in the description of the practical details of the several processes, and which, for the sake of clearness, will be divided into the *daguerrotype*, the *collodion*, the *albumino-collodion*, the *calotype*, the *photogenic* and *printing* processes, to which will be added the application of photography to other branches of art, such as *photolithographic*, *photoglyphic*, and *photogalvanographic* operations.

PRACTICE OF PHOTOGRAPHY.—Before immediately entering upon a detail of working, it may be well to remark that in the images formed in the camera obscura the lights and shades are true to nature, but the position of objects is reversed, as regards right and left. In fixing these images by photography upon various tablets, the object is to produce impressions true to nature in the lights and shades, and non-reversed.

There are two ways of doing this. According to one method a *negative* photograph is first produced, from which, by a second photographic process, a *positive* photograph is obtained. The other method consists in obtaining a positive photograph by one operation.

By a *negative* is meant a transparent photograph in which the lights and shades are the opposite to those in nature, and the objects reversed as regards right and left. By a *positive* is meant a photograph in which the lights and shades are true to nature.

Two direct positive processes are commonly used; they are called the *daguerrotype* and the *positive collodion* processes. In the former the picture is

produced upon a silvered copper plate; in the latter upon glass, or some black even substance, such as glazed leather, oil-cloth, enamelled iron, *et cetera*.

THE DAGUERRETYPE PROCESS.—This process is now hardly ever practised in Great Britain, and but partially in America; nevertheless, a short description of it will not be uninteresting:—A silvered copper plate is first polished to the utmost; it is then rendered sensitive to light, by being exposed to the fumes of iodine and bromine, after which it is presented to the image in the camera; no visible picture is produced until the plate is submitted to the vapor of mercury, which adheres only to the parts that have been acted on by light, thus forming the lights of the picture, whilst the blackened polished metal forms the shadows. The subsequent operations consist, first, in removing the film of argentine, iodide, and bromide from the plate by immersing it in a solution of hyposulphite of soda, and next in fixing the picture permanently to the plate by means of a boiling solution of *sel d'or*—hyposulphite of gold and soda—which at the same time greatly improves the appearance of the picture. Such is a brief sketch of this very beautiful process. It now remains to describe the operations more in detail.

To Polish the Plate.—The plates are polished by dusting a little finely-powdered rotten-stone upon them, and rubbing them all over with a little cotton or fine flannel dipped in a solution of nitric acid in twenty parts of water. When all dirt is removed, they are dried by friction with fine dry cotton or flannel. Finally, the slight scratches produced in the first operation are effaced by rubbing the plates on pads of velvet nailed to a board, and upon which powdered charcoal of different degrees of fineness is laid. When perfectly clean and polished, the breath should condense upon it in an even sheet.

To Excite the Plate.—Two coating boxes are required for this operation, one to contain iodine, the other lime saturated with bromine. Those with glass pans are the best. The iodine is spread evenly over the bottom of one of these boxes, and the bromide of lime to the depth of an inch over the bottom of the other. The plate is then laid with its face downwards over the iodine, for a minute or two, until it assumes a deep yellow color; it is then removed, and laid over the bromine for a minute, or until it assumes a bluish steel color; and then again over the iodine for a few seconds, after which it is ready to be exposed in the camera. In exposing the plates to the exciting media, the time of exposure must necessarily be dependant on the temperature of the room, and consequently, there is nothing to direct the operator, except the tint of color on the polished surface mentioned above. The plate may be examined under a feeble light, until it is put over the iodine the second time; and should any accident occur in taking a picture, and the plate be exposed to light, there will be no necessity to clean and excite it again; for the mere exposure to iodine for two or three seconds will obliterate the impression, and render the plate in as good condition for receiving a fresh impression as it was before.

The Exposure in the Camera.—The exposure in the camera and development of the image should follow

the exciting of the plate as quickly as possible; nevertheless, if the sensitive plates be put into a closely-covered plate box, face to face, they preserve their sensitiveness for some hours unimpaired.

The time of exposure in the camera is a matter of critical importance, and it can only be ascertained to great nicety by experiment. The process is exceedingly sensitive and rapid, and with the full aperture of a portrait-lens, and a strong light out-of-doors, an instantaneous exposure is sufficient; but under glass, and with only a moderate diffused light, several seconds are required, and sometimes with a view-lens and small diaphragm several minutes; much of course depending upon the brightness of the object and the size of the diaphragm.

The over-exposed parts of a picture look blue, and are said to be *solarized*. The under-exposed parts appear black and devoid of detail. The photographer should avoid as much as possible too violent contrasts of light and shade in the model, and aim at half tone and modulation of shade; and in exposing a plate, the exposure should be timed with reference to the shadows, and the lights left to take care of themselves. There are differences of opinion with respect to the comparative sensitiveness of the daguerreotype and collodion processes, but the positive collodion process is generally believed to be the more sensitive of the two.

The Development of the Image.—On removing the plate from the camera, it is placed in a mercury box containing the vapor of mercury heated to about 140°. The most convenient mercury box is that used in America; it is made of iron, and shaped like an inverted pyramid, the mercury being at the bottom, and the plate laid horizontally over it. It is provided with a thermometer which indicates the temperature, and the mercury is heated by a spirit-lamp placed underneath. The surface of the mercury should be perfectly clean; and it will frequently require filtering either by squeezing through a wash-leather, or passing through a glass filter with a small aperture made for the purpose. The time of development depends upon the size of the box, the temperature, and the quantity of quicksilver used, and it may vary from two or three minutes to a quarter of an hour—about five minutes is a good average time. The development should not be stopped until all the details in the shadows are fully out. If continued too long, or if the mercury be too hot, the picture appears hazy, the shadows assuming a peculiar speckled appearance.

The Fixing and Gilding.—On removal from the mercury box, the picture may be exposed to daylight, as no further development can take place. In order to remove the iodine and bromine from the plate, it must be immersed in a solution of hyposulphite of soda in distilled water. The strength is immaterial; one part hyposulphite to six parts of water will do very well, but it is important always to filter the solution through blotting paper. It should be poured into a flat dish, and the plate immersed face upwards in such a way as that a wave of liquid flows quickly over it, and two waves not allowed to meet upon it in any part. The yellow film upon the plate is now quickly cleared off, and the polished silver with the grey image upon it

exposed to view. The plate must then be well washed with distilled water, drained, and laid accurately horizontal upon a levelling stand, ready for the operation of gilding. This is accomplished by pouring upon the plate through a funnel, having a tuft of cotton wool in its neck, as much of a solution of hyposulphite of gold and soda—*sel d'or*—as it will hold without any running over, and then heating this liquid to the boiling point by passing a spirit-lamp backwards and forwards under the plate. The *sel d'or* solution is made by dissolving half a grain of the compound hyposulphate in an ounce of distilled water. While boiling the solution upon the plate, bubbles form but must not be allowed to stick to it; this is prevented by tapping the foot of the levelling stand occasionally with the bottom of the spirit-lamp, and thus communicating a vibration to the plate. As soon as the liquid becomes hot, the lights of the picture darken; but after a few seconds they begin to get whiter, and the blacks blacker. In the course of a minute or two, the appearance of the picture is greatly improved, and the process is then arrested by pouring off the hot liquid, and washing the plate with cold distilled water poured over it from a bottle having a glass tube fitted into the cork; after which it only remains to dry the plate, and the picture is finished. This is done by taking the corner of it in a pair of pineers, holding it at an angle of about 45° to the floor, and passing the flame of a spirit-lamp underneath, beginning with the upper corner, chasing the line of wet from the upper to the lower corner, and removing the last drop with blotting paper.

The rationale of the daguerreotype may be inferred from what has been said under the chemistry of photography. A film of iodide and bromide of silver, sensitive to light, results from the exposures in the exciting boxes. This attenuated coating is reduced by the chemical rays of the light impinged upon it, to the state of a subsalt; and upon exposure to the mercurial vapor the metal deposits upon the part so attacked. All the unaffected argentine surface is deprived of the sensitive iodo-bromide of silver by the solution of alkaline hyposulphite—and the final treatment with gold solution has the effect of depositing the gold by electrolysis upon the parts of the plate acted upon by the light.

The daguerreotype process may be considered the most perfect of all the photographic processes at present known; for certainly it stands unequalled for microscopic perfection of detail, modulation of shade, and beauty of half-tone; nor is this superiority to be wondered at when it is considered that the chemicals are applied in the form of impalpable vapor, and that the tablet is a highly polished metal plate; while in other processes the chemicals are either contained in a coarse material like paper, or else in a gummy film, which is spread upon glass, leather, or enamel.

Daguerreotypes are permanent when the manipulation is properly performed, the plate thoroughly washed, and carefully sealed up in an air-tight case. In order to avoid the reversion of the image, a reflector must be used in front of the lens, an expedient which is not necessary in any other process.

THE COLLODION PROCESSES, POSITIVE AND NEGATIVE.—Collodion, so named from its adhesive nature, is a gelatinous substance made by dissolving pyroxylin—gun-cotton—in a mixture of ether and alcohol. It is extensively used in photography, as a vehicle for supporting the sensitive chemicals.

The reader will find a detailed account of the methods followed in the preparation of gun-cotton, or pyroxylin, *ante* Vol. II., page 329, and a brief description of the process for converting this material into collodion at page 334. It may be convenient, however, to repeat shortly in this place, the process of making plain collodion with a special view to its application for photographic purposes:—Mix together in a large and perfectly dry basin equal parts, by measure, of commercial oil of vitriol and nitric acid, specific gravity 1.42. The temperature of the mixed acids rises to about 150° ; and it must be maintained at that temperature by placing the basin in hot water, if necessary. The operation must be conducted under a chimney in order that the fumes may escape. Then immerse in the mixture, in small quantities at a time, the best cotton wool, such as is manufactured for chemical purposes, pulled out into thin flat pieces. Put as much into the liquid as it will conveniently cover, and stir it about with two thick glass rods for the space of five minutes. Then pour the whole contents of the basin into an earthenware colander, so that the acids may drain off, and wash the cotton thoroughly by putting it for a minute under a tap; after which throw it into a pail of water and stir it about with the glass rods. Change the water, and continue this washing for some minutes, squeezing the gun-cotton between the hands occasionally; and, lastly, put it into warm water, to which a little soda has been added, in order to neutralize completely all trace of acidity; after which wash the gun-cotton again thoroughly in several changes of water, and let it soak in water for an hour or two; then remove it, squeeze it, and spread it out to dry spontaneously in a safe place, or hang it up to dry in a net suspended from the ceiling. When nearly dry pull it out into small pieces or tufts, and in this state let it get thoroughly dry. It should then be put away in a tin canister. It is an exceedingly inflammable and dangerous substance, and has been known to decompose by keeping, and evolve dense suffocating fumes. Great care should therefore be taken in the manufacture and preservation of gun-cotton.

The proper strength of the nitric acid should be strictly observed; for there are several kinds of gun-cotton, some of which are quite unsuitable for the purpose. For instance, if the strongest nitric acid is used, specific gravity 1.5, the gun-cotton is of the most explosive kind, and will not dissolve in ether and alcohol; if, on the other hand, the nitric acid be too weak, the gun-cotton is but imperfectly soluble, and a good deal of it becomes disintegrated, and is lost in the washing. But even supposing the gun-cotton to dissolve perfectly in the ether and alcohol, the collodion may still be faulty; for if the acids are too strong, the collodion film when spread upon a glass plate contracts greatly on drying, and if too weak, the film is opalescent, and partially opaque like tissue paper, instead of

being transparent and structureless. Then, again, the temperature of the acid mixture is a matter of importance; for if it be too low, the negatives are deficient in density; and if too high, the collodion becomes insensitive, and fails to give the half-tones of the picture—the blacks assuming excessive density, while the lights remain clear and devoid of detail. On the whole, the best proportions, strength, and temperature of the acid mixture appear to be those indicated in the former paragraph.

Having thus shown how to make photographic pyroxylin, it remains to describe the mode of dissolving it in a mixture of ether and alcohol, so as to produce *plain collodion*. This is done as follows:—Mix together absolute ether, specific gravity .725, one part by measure, and absolute alcohol, specific gravity .800, three parts by measure; and to every fluid ounce of this mixture add from six to eight grains of pyroxylin, according to the thickness of film required. Shake the mixture well for some minutes. The pyroxylin quickly dissolves. The bottle should then be put aside and remain undisturbed for several days, at the end of which time the clear liquid may be drawn off by means of a siphon from any sediment which may form, and it is then ready for use. The ether and alcohol employed may be either pure or methylated. *Absolute* methylic ether and alcohol appear to answer the purpose exceedingly well, and are much cheaper than pure spirits, since they pay no duty. They have also this advantage, that the iodized collodion does not become so quickly deteriorated as when pure spirits are used.

For making collodion, the following proportions *by weight* have also been severally recommended:—

Gun-cotton,	1	....	5	....	1
Ether,	120	....	110	....	196
Alcohol,	60	....	20	....	12

Whatever be the quantity of the fluids taken to dissolve the cotton originally, the solution, if too thick, can be easily diluted to the suitable degree. This is known by pouring a small portion of it on a plate of glass, on which it should flow freely, and leave at the same time a firm film of collodion, and so cohesive as not to break under a stream of water. Any fibres of the cotton that may remain undissolved may be separated by filtration. DELAMOTTE and others add a few drops of ammonia to the bulk of the collodion to prevent acidity.

To iodize the collodion many receipts are followed. ARCHER's method is to make a saturated solution of iodide of potassium in alcohol, and to add as much iodide of silver as the liquid will dissolve, even with repeated shakings, and, after the menstruum clarifies, to add a sufficient quantity to enable it to take up a coating of silver from the argentiferous bath. Generally the iodizing solution is made differently for positives and negatives. For negatives it is made by dissolving fourteen grains of iodide of potassium to the ounce of alcohol, specific gravity .825; for positives by dissolving ten grains of iodide of potassium and two grains of bromide of potassium to the ounce of alcohol, specific gravity .825. In order to iodize the collodion, one part by measure of the iodizing solution is added to three parts by measure of the

plain collodion. The mixture is shaken well together, and may be used at once.

Sometimes iodide of ammonium and fluoride of potassium are used for positive pictures, in the proportion of forty-two grains of the iodide and two of the potassium salt to six ounces of the collodion. The two salts are put into the sized bottle specified, and five or six drops of water added to moisten, but not to completely dissolve them, and the plain collodion afterwards added. On shaking the whole, and allowing it afterwards to rest, complete solution will take place. The following are other proportions which work well:—

Collodion,	6 ounces.
Iodide of ammonium,	53 grains.
Fluoride of potassium,	2 grains.
Water,	5 drops.
Collodion,	6 ounces.
Iodide of potassium,	12 grains.
Iodide of silver,	7 to 8 grains.

When methylated spirit is used, and the gun-cotton properly washed, the iodized collodion remains colorless; but when pure spirit is employed, it turns at once of a pale yellow color, which gradually deepens by keeping to an orange-yellow, and ultimately to a deep red; the collodion is then insensitive and useless.

The bottle containing plain collodion should never be shaken, and the iodizing solution should be filtered through blotting paper. The iodides of cadmium or ammonium are liable to objections, for the salts of cadmium impair the fluidity of the collodion and put the nitrate-bath out of order, while the salts of ammonium are exceedingly unstable. Collodion iodized with iodide of cadmium does not become discolored by keeping; but, although not visibly deteriorated, its good qualities are nevertheless impaired.

THE NEGATIVE COLLODION PROCESS.—The operations for taking negative collodion pictures consist in cleaning the glass plate, coating it with iodized collodion, rendering it sensitive by immersion in the nitrate of silver bath, exposing it in the camera, developing the latent image, removing the redundant chemicals, and washing, drying, and varnishing the picture.

Patent plate-glass should be employed for negatives; because plates of flatted crown or common window-glass, not being perfectly level, are liable to get broken in the operation of printing. The edges of the plates should be ground by rubbing them in a notch made in a piece of stone.

To Clean the Glass Plates.—Wash them well with water, and scrub them with a hard brush till they appear to be clean. Then rub them all over with a tuft of tow dipped in dilute nitric acid; wash them again thoroughly in several changes of water, or under a tap, wipe them dry with clean linen cloths, and finally polish them with a washleather or piece of cambric. When a plate is perfectly clean, the breath condenses upon it in an even sheet free from irregular markings.

To Apply the Collodion.—Hold the plate horizontally by one corner in the left hand, or put it upon a platchholder, blow off any dust that may have settled upon it, and pour in the centre of it a circular patch of collodion rather more than half as large as the plate. Then tilt the plate so as to allow the collodion to run

towards the thumb, but without actually touching it, and afterwards to the adjacent corners, and pour off the surplus from the corner diagonally opposite to that by which the plate is held, into the bottle. After which rock the plate backwards and forwards with the corner upon the neck of the bottle, so as to prevent the formation of lines in the collodion, and place it upon the dipper of a nitrate-bath, where it may remain from one to five minutes according to the temperature. It is now ready to be excited.

To Excite the Collodion Film.—This is done by immersing the plate, as soon as the film has set, in a bath of nitrate of silver, made by dissolving thirty grains of pure nitrate of silver to the ounce of distilled water. The bath should be an upright vessel, of glass or porcelain, and moulded in one piece. Gutta-percha is frequently employed; but although very good for the purpose, it is hardly so trustworthy as glass, and some operators have complained of gutta-percha baths communicating impurities to the nitrate-bath, and putting it out of order. The plate should be completely immersed without pausing, as that would occasion a line across it. It should remain in the bath during a minute, moved up and down two or three times to take the ether from its surface, and allow an even coating of the silver salt to be formed. After this it is permitted to remain during two or three minutes longer according to the temperature and the strength of the bath. Three minutes suffice when the bath is at 60° to 65°. The film will now exhibit an even coating of yellow iodide of silver. It should be drained for a few seconds over the bath, the back of it wiped with blotting paper, and then put into the dark slide.

It is important that the nitrate-bath be made with pure nitrate of silver, obtained by dissolving silver in pure nitric acid. When common commercial nitrate of silver is used, it is impossible to obtain good results with certainty and uniformity, and it generally becomes necessary to add acetate of silver to the bath in order to obtain sufficient density in the blacks. When the nitrate of silver is pure, and nearly all the free nitric acid got rid of by redissolving and recrystallizing it, the bath works well without any additions. It gradually acquires iodide of silver, nitrate of potassa, and organic impurities by use.

It may be remarked that by leaving the plate in the bath longer than is requisite, and when the collodion is tender, or has been introduced before it has sufficiently dried and acquired proper tenacity, it frequently cracks and drops in fragments into the bath. If the collodion be good and moderately old, the excited plate possessing an opal hue suffers no injury by remaining a little longer immersed; but when the bath is fresh, it should be taken out as soon as it becomes sufficiently excited, otherwise the iodide on the plate will be attacked. Some photographers obviate this inconvenience by adding about one grain of iodide of silver to the ounce measure of silver solution.

The Exposure in the Camera.—This is a point on which it is impossible to give exact directions; but the faults due to over and under-exposure may be clearly pointed out. In an under-exposed picture the details of the shadows cannot be brought out, and the

blacks acquire excessive opacity. In an over-exposed picture the details of the shadows appear before the blacks have had time to become sufficiently intense; and, since the development cannot then be sufficiently prolonged, the result is a flat feeble picture, deficient in contrasts.

The proper time of exposure depends on the aperture of the lens and its focal length, and it varies *directly* as the square of the focal length, and *inversely* as the square of the diameter of the aperture, when different lenses are employed. By the focal length is meant the distance of the *focus*, or point of convergence of the rays, from the centre of the lens; that is, the distance at which the image on the screen appears quite distinct.

To Develop the Latent Image.—Hold the plate in the left hand by one corner, or place it upon a leveling stand, and pour over it a sufficient quantity to cover it, of either of the following mixtures:—

	Hunt's	Delamotte's.
Pyrogallic acid,	1 grain... 5 grains... 9 grains.	
Water,	1 ounce... 10 ounces... 3 ounces.	
Glacial acetic acid, ..	1 scruple. 40 drops.... 2 drachms.	

In a minute or less the dark parts of the image appear, and are soon followed by the half tones and finer details in the shadows. Let the developer flow backwards and forwards over the plate until the picture is fully out, and sufficiently dense. If the collodion is good, and the nitrate bath in good order, the development need not be hurried, but may occupy several minutes. Under some circumstances it may be well to add a few drops of solution of nitrate of silver to the developer in a measure, and pour it again over the plate, in order to give the blacks greater intensity.

When the negative is fully out in all its details, wash it well with water.

Some persons use a developer composed of protosulphate of iron, thus:—

Distilled water,	1 ounce.
Protosulphate of iron,	5 grains or more.
Acetic acid,	5 minims or more.

A shorter exposure will then suffice, and the contrasts of white and black are less violent, and half tones prevail to a greater extent. The mode of treatment is the same as with pyrogallic acid. Nitrate of the protoxide of iron is sometimes substituted for the sulphate.

To Fix and Finish the Picture.—When the plate has been well washed after the development, by pouring water over it from a jug, the yellow iodide of silver should be dissolved out by means of either a saturated solution of hyposulphite of soda, or a solution of cyanide of potassium—strength about five grains to the ounce of water. This should be poured over the plate, and should be allowed to run backwards and forwards over it until the whole of the yellow iodide of silver in the plate has disappeared; after which it should be thoroughly well washed, by pouring water over it from a jug, and set up to drain and dry; or it may be dried before a fire. It is then ready to be varnished.

The best kind of varnish to apply to a cold plate is made by dissolving powdered dammara resin in benzol. This is poured over the picture in the same way as the collodion on the plate. It dries in a few minutes. But a better varnish, used with a heated plate, is made by dissolving shell-lac in alcohol. This is called spirit varnish. Before applying it, the plate should be heated before a fire to about 100°, and after applying it, to about 150°. When dry, this varnish is extremely hard and difficult to scratch, and it protects the picture effectually from injury in printing.

The negative is now finished. An unlimited number of prints may be taken from it, by the printing process.

THE POSITIVE COLLODION PROCESS.—A collodion negative is intended to be looked *through*; a collodion positive to be looked *at*. A negative must possess density when looked through, and the color of the surface deposit is of no consequence. A positive need not possess density when looked through, and the color of the surface deposit is of great consequence, for it should be white. Hence the difference between the processes. Now it is found that organic matter combined with the silver of the image gives density and a bad surface color; while the absence of organic matter gives a good surface color, but no density. It is evident, therefore, that in the positive process an inorganic developer, such as protosulphate of iron, must be used instead of pyrogallie acid, which is an organic substance; while the nitrate bath should be acidified with nitric, and not with acetic acid. Bearing these things in mind, the processes become nearly identical in manipulation; the only difference being, that in the development of positives, the operation is much quicker, since it is only a superficial indication of detail that is wanted, and not density.

A positive is true to nature, because wherever the light acts a white precipitate of metallic silver is formed; while the parts where light does not act remain clear glass, and these are converted into dense blacks by simply applying black varnish to the back of the glass.

The nitrate-bath for positives is composed of—

Distilled water,	1 ounce.
Nitrate of silver,	40 grains.
Nitric acid,	1 minim.

The developer is made thus:—Dissolve one ounce of powdered nitrate of baryta in sixteen ounces of boiling distilled water, and when cold, add two drachms of nitric acid, specific gravity 1.42. Next add one ounce and a half of powdered protosulphate of iron. Shake well until the iron salt is dissolved. The mixture becomes white and turbid, in consequence of the formation of sulphate of baryta. Let this settle to the bottom of the bottle, and then decant and filter the clear liquid, which is of a green color, and is a mixture of protonitrate and protosulphate of iron. Add two ounces of alcohol to make it flow better over the collodion film. It is now ready for use. It deteriorates by keeping, and acts much better when fresh.

One ounce of protosulphate of iron decomposes

about one ounce of nitrate of baryta, forming insoluble sulphate of baryta, and soluble protonitrate of iron. The remaining half ounce of undecomposed protosulphate of iron forms the energetic part of the developer.

The nitric acid should be added to the nitrate of baryta, and not after the addition of the iron salt, as some sesquioxidation of the iron might then occur, which would occasion a browning of the solution, and cause a precipitate.

Some operators use nitrate of potassa instead of nitrate of baryta, but this is not right, because the sulphate of potassa formed is soluble, and remains in the solution, while the sulphate of baryta, being insoluble, can be removed. The use of acetic acid instead of nitric acid, is also wrong, because it injures the color of the whites, being an organic substance.

The development of a positive only occupies a few seconds, and it must be stopped as soon as there is the faintest indication of the details in the shadows. The plate should then be well washed to remove all traces of iron, and the picture fixed with a liquid composed of:

	Parts
Water,	60
Cyanide of potassium,	6
Nitrate of silver,	1

The picture should be fixed with cyanide of potassium, and not with hyposulphite of soda, for two reasons;—first, because the cyanide removes more perfectly any organic compound of silver which might injure the color of the picture; and, secondly, because the hyposulphite of soda injures the color by blackening the silver.

A black ground may be given to the picture, either by backing the plate with velvet, or by passing upon it black varnish. This is made by dissolving asphaltum in benzol, and adding a little india-rubber to prevent it from cracking, a fault to which it is very liable. Printers' ink makes a good varnish, which does not crack. To apply it, rub it upon the back of the glass, and also upon a piece of paper, and then press the blackened side of the paper against the blackened side of the glass, and put the picture at once into its case. Collodion positives should always be taken in a non-reversing slide.

Positive pictures may be obtained from negatives in a variety of ways. *Fry*, after developing the image with the prosalts of iron above-described, changed the negative to a positive by pouring upon it a mixture of pyrogallie acid and hyposulphate of soda which had undergone partial decomposition, and warming gently. By this treatment the darkened parts are rendered brilliantly white from the formation of metallic silver. *Archer* pours a mixture of one part of a saturated solution of protochloride of mercury— Hg Cl —acidulated with hydrochloric acid and six parts of water upon one corner of the plate, and allows it to flow over the fixed negative picture. At first the shades are deepened, but quickly the appearance alters, and a very delicate white picture results. This picture may be alternately changed from positive to negative, and *vice versa*, by the agency of ammonia and the mercurial compound above applied alternately.

THE DRY COLLODION PROCESS.—In the former processes the excited collodion film is exposed and developed in its wet state, immediately after its removal from the nitrate-bath; but by attending to the following directions, it may be used dry, and kept for many months in a sensitive state. On removal from the nitrate-bath wash the film thoroughly in distilled water, so as to remove as much as possible of the free nitrate of silver from it. Then pour over it a tepid solution of gelatin, made by dissolving about six grains of gelatin to the ounce of distilled water, and adding about one drachm of alcohol, specific gravity .820. Set up the plate upon one corner against a wall to drain and dry in the dark. The exposure in the camera must be about six times longer than with wet collodion.

To develop the picture, first immerse it for a few minutes in a dish of distilled water, then pour over it the usual pyrogallie acid developer, to which a drop or two of a thirty-grain solution of nitrate of silver are added. The image comes out, and is developed as quickly as an ordinary wet collodion plate. It is then washed and finished in the usual way.

It is important to observe in this process that the measure in which the developer is mixed should be chemically clean; it ought, therefore, to be cleansed with cyanide of potassium, and well washed after every picture. In the ordinary wet process it is not absolutely necessary to take this precaution, although it is well to do so. The nitrate of silver added to the developer should be fresh solution, and not taken from the nitrate-bath.

The process just described was invented and patented by Dr. HILL NORRIS of Birmingham. It is extensively employed, and gives universal satisfaction. A very similar process has been introduced lately by Mr. FOTHERGILL; it consists in substituting albumen for gelatin, all the other operations remaining the same. When the plates are not required to be kept for more than a few days, this process succeeds pretty well; but for long keeping Dr. NORRIS's mode is the best. In FOTHERGILL's process the albumen is applied to the plate after washing off the nitrate of silver, and the plate is then washed again so as to remove the albumen. The pores of the collodion are probably filled with a compound of albumen and silver, which has been improperly termed *albuminate of silver*.

THE COLLODIO-ALBUMEN PROCESS.—This is a dry negative process which differs in an important particular from Dr. HILL NORRIS's or Mr. FOTHERGILL's. After the excited collodionized plate has been washed with water, iodized albumen is poured over it, and it is either allowed to dry, or dried before a fire. It is then insensitive to light. It is excited by immersing it in a bath of acetate of silver; after which it is washed and dried. The development is effected by immersing the plate in a solution of gallic acid, to which a few drops of acetate of silver are added. The negative is then fixed and finished in the usual way.

The iodized albumen is composed of about equal parts of albumen and water, to every ounce of which about six grains of iodide of potassium are added. This is then beaten up to a froth, and allowed to settle in the usual way. The bath of acetate of silver

contains fifty grains of nitrate of silver and one drachm of acetic acid to the ounce of water.

This process is more complicated and troublesome than any other, and the negatives are of a bad color, having a strong tinge of yellowish-green.

PRESERVATIVE PROCESSES.—In certain processes, instead of allowing the excited collodion film to get dry, a sirup is poured over it, which is completely washed off before the development. Golden sirup, honey, and oxymel have been employed. The former is probably the best, from its not containing either grape sugar—which is a reducing agent and causes partial decomposition and stain, when the plate is kept too long—or an acid, which renders the plate extremely insensitive, and destroys the half-tone. In using golden sirup, the nitrate of silver is first washed off and then the sirup applied; after exposure the plate is well washed to remove the sirup, and then developed as in Dr. NORRIS's process.

The objections to the moist preservative processes are, that wet sticky plates are liable to contract dust, and cannot be closely packed one upon the other for a journey as dry plates can. This mode of operating is, however, useful when the plate is prepared in the morning and developed in the evening of the same day.

To describe fully all the difficulties which beset the tyro in the manipulation of the various collodion processes, and to point out the causes of failure and the means of remedying them, would occupy too much space to be attempted in this work. In fact, each separate process, to be thoroughly explained and discussed, would occupy a volume. There is, however, a strong analogy between them all, and a theory which appears to include them all. This the Editor will now proceed to discuss.

THEORY OF THE COLLODION PROCESSES.—The sensitive collodion film is composed of iodide of silver, free nitrate of silver, and collodion. The iodide of silver is formed by immersing the iodized collodion film in the bath of nitrate of silver, so that iodide of potassium, plus nitrate of oxide of silver, becomes iodide of silver, plus nitrate of oxide of potassium—that is, nitrate of potassa. Now the collodion in the above combination appears to have a retarding effect on the action of light, because when a mixture of iodide of silver and nitrate of silver alone is exposed to light, it darkens more rapidly than when collodion is present. The collodion must not, therefore, be considered as an accelerator, but as the vehicle for supporting the sensitive chemicals upon the glass, and forming with the reduced silver an opaque compound in the darker parts of negatives. In the development of the picture, the pyrogallie acid accelerates the reduction of the silver salts on those parts on which the rays of sunlight have fallen, producing finely-divided metallic silver, which constitutes the blacks of the negative. The acetic acid, added to the pyrogallie developer, prevents its spontaneous or too rapid decomposition when mixed with the nitrate of silver. When, in the development of a positive, protosulphate of iron is used instead of pyrogallie acid, the difference between it and the organic acid mentioned is attributable to the fact, that it does not reduce as much of the metal as

the latter; consequently the precipitate is thin and transparent, and looks white when viewed by reflected light.

When cyanide of potassium is used to fix the picture, that is, to remove the iodide of silver, it has but little action on the image, while it decomposes the iodide of silver, and forms a soluble double cyanide of silver and potassium, together with iodide of potassium. When hyposulphite of soda is used, the iodide of silver is decomposed, and the products are a soluble double hyposulphite of silver and soda, together with iodide of sodium.

It appears that the maximum degree of sensitiveness in the film, is when it contains a certain excess of free nitrate of silver; so that, in the dry processes, the sensitiveness is reduced to a minimum by washing off the free nitrate; and in developing dry plates it is necessary to add nitrate of silver to the developer, to insure depth of shade by the deposition of more silver on the affected parts. It is necessary to wash off the free nitrate of silver from the plate for this reason, that if allowed to remain and get dry in the film it becomes concentrated by evaporation, and a concentrated solution of nitrate of silver has the property of dissolving iodide of silver, and rendering the film transparent and insensitive, by forming a salt called iodonitrate of silver.

THE ALBUMEN NEGATIVE PROCESS UPON GLASS.
—As indicated in the brief historical notice to this article, albumen has long been employed upon glass as the basis of photographic pictures, so likewise has gelatin, and the results which both these yield are very satisfactory. The principal operations concerned in taking the picture with prepared albumen are, with few exceptions, the same as those practiced in working with collodion. The following description will indicate any slight differences in the manufacture.

To Prepare the Albumen.—Collect in a basin the whites of a number of eggs, carefully separating the germ, and all portions of yolk. To each ounce of this albumen add one drachm of distilled water, in which are dissolved six grains of iodide of potassium; also to every five ounces of the mixture add one drop of ammonia. Beat the whole to a stiff froth with a bunch of quills, and allow the liquid to settle till the following day.

To Albumenize the Plate.—The glass plate must first be cleaned very thoroughly, dried, and polished with a cambric handkerchief just before use. Attach to the under side of it a gutta-percha plateholder, having a wooden handle a foot long. Then breathe on the plate, and, holding it horizontally in the left hand, pour upon the centre of it a sufficient quantity of the albumen from the basin to cover it, allowing the albumen to filter through an opening in the dry froth or crust. Make the albumen flow backwards and forwards over the plate three or four times, and then allow the excess to run off into a separate basin, from which it must be carefully filtered before being used a second time. In coating the plate, be careful to remove with the point of a fine camel-hair pencil any air-bubbles which may have formed upon it. Next, take the handle of the holder between both hands, and, with the plate in a vertical position, spin it round quickly for a minute

or so, in order to drive the albumen to the edges by centrifugal force. This done, remove the excess of albumen from the edges by means of a pipette, and dry the plate before a clear fire, keeping it rotating all the time by means of the handle, as before directed. When dry it is ready for the next operation. Albumenized plates may be put away in a platebox, and kept in a dry place for a considerable time without deterioration. Care must be taken in the operation of albumenizing the plate that no particles of dust adhere to it.

Many practitioners find it more convenient to apply a dilute solution of albumen at first, and then by means of a pipette, in which as much of the prepared albumen has been taken up as will suffice for one plate, applying it in horizontal lines almost bordering upon one another. A gentle horizontal oscillating motion afterwards serves to spread it in an even layer, leaving an excess in no part. There are many other methods recommended in treatises and journals, but they need not be dwelt upon here; for every operator, knowing that the desideratum is to get a smooth homogenous layer of the albumen on the plate, will contrive in his own peculiar way to do so effectually.

To Excite the Plate.—Place it on a dipper, and immerse it quickly and without hesitation in a vertical bath of acetate of silver, made thus:—Distilled water one ounce, nitrate of silver fifty grains, glacial acetic acid one drachm. Leave it in the bath for a couple of minutes, then wash it well in clean water, and lastly in distilled water, and set it up to dry. When dry put it away in the platebox until ready for use in the camera. It may be preserved in a sensitive state for several days. Some persons add a few drops of a solution of iodide of potassium to a new nitrate-bath, and filter it on the following day, in order to saturate it with iodide of silver. When this is done a new bath is not so liable to attack the iodide of silver in the film.

The Exposure.—Albumenized plates, from which the excess of free nitrate of silver has been removed by washing, are, whether used in a dry or wet state, extremely sensitive to light; but, when only slightly washed, exposed at once, and developed with a strong developer, a much shorter exposure is sufficient. This should be timed solely with reference to the shadows, the lights being left to take care of themselves. When the camera is properly constructed, so as to prevent stray light from falling on the plate, it is hardly possible to over-expose a dry, washed, albumenized plate.

To Develop the Image.—Immerse the plate in distilled water; then place it on a levelling-stand, and pour over it a saturated solution of gallic acid, to which a few drops of acetate of silver have been added. The development occupies about twenty minutes.

To Fix the Picture.—Wash the plate in rain water, and pour over it a nearly-saturated solution of hyposulphite of soda. This will quickly remove the yellow iodide of silver from the film. Then wash the plate well under a tap, and dry it before the fire.

The negative may be varnished with any good varnish, but this is not always done.

A great many modifications have been adopted with albumen to give greater sensitiveness and quickness of

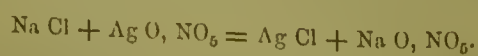
effect. Serum of milk, honey, and a dense solution of sugar have been mixed with the albumen, in order to get a coating of silver possessing more body than can be obtained by the albumen alone. HUNT introduced the use of fluoride of potassium mixed with iodide; and this method, in the hands of M. BLANQUART EVERARD, is said to be so sensitive as to give pictures on instantaneous exposure.

THE CALOTYPE OR PAPER PROCESSES.—These processes are founded on the same principle as the collodion and albumen methods, the only difference being that the vehicle for supporting the chemicals is paper instead of a collodionized or albumenized plate. They may be divided into two classes according to the mode of operation pursued, and the chief difference between them consists in the mode of rendering the paper sensitive, that is, in the order in which the ingredients are introduced, the mode of development being nearly the same in all, and merely involving a difference in the strength of the developer and the mode of applying it.

Considerable attention must be paid to the quality of the paper, for every kind is far from being applicable. That most suitable is a white paper as pure as possible from mineral matters, having a close fibre, sized either with starch or gum, and well pressed, to render the surface fine and even and homogeneous throughout. Unsized paper does not give satisfaction when silver salts are the sensitive agents, as it absorbs too much of the materials, and the picture is developed rather in the body of the material than upon its surface. These requirements are happily understood to a great degree, and manufacturers devote attention to the production of a paper possessing many of the qualities which the photographer requires.

The calotype processes may be classed under two heads. In the first the paper is coated with insensitive iodide of silver, and then excited by a weak solution of acidified gallonitrate of silver; in the second class, the paper is first coated with an alkaline iodide, and then excited by immersion in a *strong* bath of nitrate of silver, the excess of free nitrate being subsequently removed by washing. Of these, one will be selected for minute description, which appears to be, of all the calotype processes, the simplest in manipulation and most scientific in principle. In the processes of Class I. the paper is iodized with iodide of silver; in those of Class II. with a soluble alkaline iodide. The first kind of iodized paper may, for convenience, be called *argento-iodized* paper, the second kind simply *iodized* paper.

Chloride of Silver Paper.—For a variety of purposes, more especially for copying from negative pictures, papers on which a surface of chloride of silver has been produced is extensively used. The manipulations by which the above is effected consist in first saturating wholly or in part with chloride of sodium solutions, and subsequently with those of nitrate of silver; chloride of silver is formed by a well-known process of double decomposition, thus—



The strength of the solutions employed are various, dependant always upon the amount of sensitiveness required. In practice the quantity of materials per

ounce of distilled or rain water indicated below are the most general:—

	Grains I.	Grains II.	Grains III.
Chloride of sodium,	30	25	29
Nitrate of silver,	129	199	69

These solutions are applied in even strata to the paper, preference being given by some persons to the alkaline salt, by others to the silver compound; and it would appear that the latter practice is more commendable, as it insures a surface better coated with the silver than if it were applied after the soda salt. The manner of coating these papers being the same as when preparing them with iodine compounds for taking impressions in the camera, and which is to be detailed, will not be dwelt upon. It may be remarked, however, that when they are to be used, the sensitive side should be recently washed with a dilute solution of nitrate of silver, as it adds considerably to the effect of the light upon them.

Iodide of Silver Paper.—It may be premised here that, however varied the methods of manipulation of different photographers may be, if they be not calculated, firstly, to secure a uniform coating of iodide of silver over every part of the surface of the paper; and, secondly, an even distribution of a small quantity of nitrate of silver, or, where great sensitiveness is required, of this salt mixed with a reducing agent—gallic acid—and an entire absence of alkaline salts before the paper is placed in the camera, they should not, as the science and practice of photography is at present understood, be adopted. Without these conditions being supplied good pictures cannot be obtained by this method.

CALOTYPE PROCESSES—CLASS I.—There are *two* methods which come under this head. In the first, argento-iodized paper is prepared by what is called the *double wash*; in the second, by the *single wash*. In all other respects the two methods are identical.

To Argento-iodize the Paper by the Double Wash.—Float the face of the paper on a bath containing twenty grains of nitrate of silver to the ounce of distilled water. Let it remain a minute or two in the bath, then hang it up to dry. Next immerse it in a solution containing twenty-five grains of iodide of potassium to the ounce of distilled water. Let it remain a minute or two in this solution, the exact time depending on the kind of paper employed, and requiring to be ascertained by experiment. If too short a time is allowed, the whole of the nitrate of silver is not decomposed, and the paper darkens in the light; if, on the contrary, too long a time is allowed, the iodide of potassium in the bath dissolves the iodide of silver in the paper. The time of immersion in the iodide-bath is therefore rather critical. On removing the paper from the bath, let it drain, and then immerse it in a pan of water, in which it must be allowed to soak, the water being changed several times, until the *whole* of the free iodide of potassium is removed. This soaking operation is rather troublesome, and the texture of the paper is decidedly injured by it. Should any excess of iodide of potassium remain in any part of the paper, it would decompose the weak exciting solution and produce insensitive iodide of silver, and consequently a white patch in the negative. When the paper has been sufficiently washed, hang it

up to dry. It is of a yellow primrose color. When dry, it may be kept for use in a portfolio. It is not sensitive to light.

To Argento-iodize the Paper by the Single Wash.—Lay the paper on a board with a piece of blotting paper under it, and brush over it a solution called *double iodide*; that is, a solution of iodide of silver in iodide of potassium. The best kind of brush is a large round one of camel's hair, bound with string or silver wire. Apply the solution copiously both longitudinally and transversely, inclining the board, and keeping a flowing edge. Hang up the paper to dry in a room having a pure atmosphere, free from sulphurous or other acid vapors. When very nearly or even quite dry, immerse the paper in a pan of water as before, to remove completely the excess of iodide of potassium which it contains. Two or more papers should not be soaked in the same pan, but each paper ought to have a separate one. When sufficiently washed—an operation which requires several hours—dry, and keep it for use.

The solution called *double iodide* is made by dissolving twenty grains of nitrate of silver in one ounce of distilled water, and adding crystals of iodide of potassium, a few at a time, until the yellow turbidity at first produced in the solution is quite cleared up. The quantity required is nearly half an ounce. The menstruum should be filtered before use.

Argento-iodized paper will retain its good qualities for some weeks. Some persons even affirm that it may be kept for an indefinite period in a dry place. It is said, on good authority, to be much improved by exposing it for an hour or two to strong sunshine. When this is done, it should not be excited immediately after insulation, but kept for some days previously in the dark, since it has been found that paper absorbs light in sufficient quantity to react on a sensitive surface placed in contact with it in the dark.

In comparing the two foregoing methods of iodizing the paper, it will be seen that the first is the most economical, but at the same time the least certain. A considerable quantity of iodide of potassium is wasted in the second mode of iodizing, and the washing operation is rather more tedious.

The paper having been iodized by either of these methods, may be proceeded with as follows:—

To Excite the Paper.—Make a saturated solution of gallic acid in cold distilled water, which call solution A; and another, by dissolving fifty grains of nitrate of silver in one ounce of distilled water, and adding one drachm of glacial acetic acid, which call solution B. Immediately before use, mix, in a chemically clean measure, one ounce of distilled water, fifteen drops of solution B, and about as many drops of solution A, the number of the latter depending on the temperature and kind of paper employed.

Lay the paper on a board with a piece of blotting paper beneath, and apply this mixture copiously to it with a clean Buckle's brush. Hold up the paper to drain for a minute, then abstract the surface moisture with clean blotting paper, and place it in the dark slide.

The Exposure.—The average time of exposure, with

a good light, a lens of fifteen inches focus, and a half-inch stop, is seven minutes.

To Develop the Picture.—Lay it on a board, and brush over it with a clean Buckle's brush, a mixture composed of three parts of solution A, and two parts of solution B. The picture, the darker parts of which are at first faintly visible, soon comes out of a fiery red tint. At this stage of the development it is necessary to check it, in order to obtain dense blacks instead of feeble reds in the darker parts of the negative. To accomplish this, brush over the picture, and complete the development with a solution of gallic acid alone.

Under this treatment the reds soon darken and intensify, and become eventually opaque blacks. The active development should occupy about twenty minutes. It is an excellent plan, after having brushed on the gallic acid, to lay the paper face downwards on a horizontal glass slab, on which a quantity of gallic acid solution has been previously spread.

To Fix the Picture.—When the details are fully out, and the blacks of the proper intensity, wash the negative with water, and then immerse it in a solution containing one part of hyposulphite of soda to four of water. Let it remain until the whole of the yellow iodide of silver dissolves; then wash and soak in water for several hours, changing the water several times, in order to remove the whole of the hyposulphite from the paper, and hang it up to dry.

The negative is now finished, and may be waxed at any convenient time in order to render it more transparent. This is done by melting some white wax in a vessel placed in a shallow pan of boiling water, applying it with a clean hogs'-hair paint-brush to the picture, which should be placed between sheets of blotting paper, and a moderately-hot iron passed over the whole until no shining patches of wax are seen.

There are one or two important points to be observed in this process. If the iodized paper is excited with a weak solution of aceto-nitrate of silver containing no admixture of gallic acid, it is quite as sensitive, or even *more* sensitive than before, but the negative is devoid of density, and the dark portions are grey, feeble, and metallic, like the dark parts of a collodion positive on glass when viewed by transmitted light. This shows that it is necessary to employ a substance—gallic acid—that will continue, as it were, the chemical effect of the radiant agent, or the proper tones cannot be produced. If, on the other hand, too much gallic acid is added to this solution, the redning effect will be so great that the paper is liable to become brown all over, particularly in hot weather. The process has, therefore, its drawbacks and uncertainties, particularly in that season of the year when photographic tourists are most in want of a good process. A good test of the proper state of the sensitive paper is to take a strip into the light. If it darkens instantly to a cold grey tint, incapable of being intensified by the further action of light, the negatives will probably be grey and feeble; but if it assumes a redder tint, which becomes still darker by continuing the exposure, there is sufficient matter present to give a good intense picture.

CALOTYPE PROCESSES—CLASS II.—In these processes the operations consist in first impregnating the

paper with an alkaline iodide; next, rendering it sensitive by immersion in a strong bath of aceto-nitrate of silver; and developing with gallonitrate of silver rather weaker than that used in the foregoing process.

To Iodize the Paper.—Immerse a number of sheets, one at a time, in a solution of iodide of potassium containing twenty grains of the salt to the ounce of distilled water. Let them remain together in the bath for at least a couple of hours, then hang up to dry, after which they may be kept in a portfolio for use.

To Excite the Paper.—Immerse it in a bath of acetonitrate of silver, containing thirty-five grains of nitrate of silver, and two scruples of glacial acetic acid to the ounce of water. First, float the face of the paper for a few seconds on the bath, then immerse it entirely for nearly three minutes, and then remove it into a dish of distilled water. Rinse well, then press it between blotting paper and put it into the slide, with its face to the front shutter.

The Exposure.—This is about the same as in the former process.

The Development.—The paper will scarcely exhibit any trace of an image. Immerse it in a solution of gallic acid, to which a few drops of aceto-nitrate have been added. The picture should not exhibit itself of a grey tint but red, which should darken in the course of the development to an intense black in the deepest parts. The dish should be chemically clean, and the developer should remain colorless throughout; the whites of the picture will not then be discolored, and the development will proceed much more quickly.

If the picture comes out grey and metallic, exhibiting all the detail, and having but little intensity, it indicates a want of a reducing agent in the sensitive film. To remedy this, add a little citrate of soda to the iodizing solution. This will entirely alter the character of the picture, increasing the density of the black, and also the necessary time of exposure. Sugar, honey, gelatin, and substances of this kind added in large quantity to the iodizing solution produce little or no effect. Serum of milk contains some organic salts—lactates—which are decomposed and form corresponding salts of silver.

As a rule, it may be considered that organic salts, which at once decompose nitrate of silver and form an *insoluble* organic compound with oxide of silver, act most powerfully in producing blacks; for instance, as gallic acid, which when added to nitrate of silver, forms a mixture which is *immediately* decomposed by light, metallic silver being produced. It is a convenient plan, when travelling, to develop without a dish, by turning up the edges of the picture and making it into a tray, into which the developer may be poured and spread with a glass rod.

To Fix the Picture.—Proceed as described in the former process.

Having described the simplest form of the second class of processes, it remains to indicate the various modifications which it has assumed. The first and most important of these consists in waxing the paper *before* iodizing it. This modification has received the name of the *Waxed-paper Process*.

Wax being nearly inert as regards its power of com-

bining with silver and forming an organic compound of that metal, its presence does not modify the character of the negative in any appreciable way as regards density; nor does it appear that any other good is derived from the introduction of wax in the first stage of the process, than stiffening the paper, and rendering it less liable to be torn in the various operations. The wax and fatty impurities contained in all the commercial samples cause it to repel water, so that there is some difficulty in getting a sheet of waxed paper to imbibe the solutions. This may be overcome by dissolving a few shreds of gelatin in the iodizing solution, and by adding a little alcohol to the gallic acid. In all other respects the waxed-paper process is the same as that previously described.

The other processes of Class II. are merely modifications of the waxed-paper process in its simplest and best form, as described above. They consist in adding various organic substances, such as rice-water, gelatin, honey, and the like, and also bromides, cyanides, fluorides, *et cetera*, to the iodizing solution. Most of these organic substances are nearly, if not absolutely inert, and many of the salts added are of very questionable utility. It would appear, however, that the bromide of potassium may be employed to replace the iodide of this base with a good effect, especially in taking landscape views, since it gives a better result as to light and shade. A word or two may be said on the subject of substituting iodide of cadmium for iodide of potassium in the paper processes. It is a tolerably good salt to employ when pure, and the negative is free from the white spots which sometimes occur when a crystal of iodide of potassium remains undecomposed. But the nitrate of cadmium introduced into the nitrate-bath has an acid reaction which resembles, in a slight degree, the reaction of the nitric acid. This renders the paper less sensitive, increases the difficulties of bringing out the details of the shadows, and diminishes the density of the blacks.

Before concluding an article which embraces a description of the most important modes at present known, of obtaining negatives on paper, it may be well to discuss the points in which these processes are inferior to the analogous ones on glass.

The principal fault of a calotype negative consists in the fact, that a sheet of paper, waxed in the ordinary way, is not evenly transparent when held against the light, but exhibits a granular appearance, and sometimes the marks of the wire frame used in its manufacture. Before a paper negative can be expected to rival one on glass, this radical defect must be overcome. Now, it will be found that if a sheet of paper is dipped for a minute or two in linseed oil and dried, it will exhibit precisely the same defects as one that is waxed; but if left in the oil for a week, so as to imbibe it thoroughly, it will appear as evenly transparent as could possibly be desired. It is obvious, therefore, that the radical fault of a calotype negative consists in the paper not thoroughly imbibing the wax, which would evidently be a work, not of minutes but of hours, or even days. Fortunately, however, the inconvenience may be repaired by a very simple process. If one half of a sheet of paper be immersed in a mixture con-

taining equal parts of hydrochloric acid and water, thoroughly rinsed in several changes of water, and dried, it will be found, in waxing the whole sheet, that the half which has been treated in the manner described imbibes the wax much more readily than the other half, and presents a beautifully even appearance.

A finished negative on plain paper may be treated with hydrochloric acid with perfect safety, since it does not attack the image, unless very strong.

Another frequent defect of paper negatives is a want of half tone, too great intensity in the blacks, and too little detail in the shadows. In such cases the fault may generally be corrected by lessening the quantity of the organic reducing agent, by diminishing the acidity of the nitrate-bath, and increasing the time of exposure.

Lastly, the paper processes are very insensitive when compared with wet collodion. This may proceed from the great quantity of acid used in the acetate-bath in paper work, as compared with the neutral, or, at least, but slightly acid one, in collodion work.

The best paper to employ in these processes is HOLLINGWORTH'S *thin* photographic paper; WHATMAN'S is also recommended.

THE PRINTING PROCESSES.—There are several methods of printing positives from a negative. Some of these consist in producing prints upon paper, others in producing prints upon glass, which are intended to be viewed as transparencies. The negative processes are always employed for the latter, and the negative is either copied by superposition upon a dry albumenized or collodionized plate, or by means of a lens upon a wet one. In the former case, an exposure of a second or two to diffused light is sufficient. In the latter, a portrait lens is employed, with a stop between the lenses, and the time of exposure depends on the size of the stop. The negative should be so placed as that the light from the northern sky is transmitted through it. Stereoscopic transparent prints are very beautiful when properly executed.

There are many ways of printing upon paper. They may be classified as *carbon printing*, *uranium printing*, *ink printing*, and *silver printing*. These various processes differ in principle, and must be treated separately.

Carbon Printing.—This process is the most economical, simple, and permanent of any. As first practised and published by Mr. POUNCY of Dorchester, it consists in blackening a sheet of paper all over with a mixture of vegetal carbon, gum arabic, and bichromate of potassa, drying it, and exposing it to light under a negative. Where the light acts the bichromate is reduced, and the black mixture rendered insoluble. The paper is then immersed for some hours in water, which entirely removes the unaltered carbon mixture from the paper, leaving the lights tolerably pure. The print is then finished.

Simple as this process may appear, it was found to succeed only in the hands of the inventor, who disposed of it for a sum of money, reserving to himself the sale and secret of a peculiar paper which he professed to be essential to its success. Even in Mr. POUNCY'S prints the lights were by no means quite pure, and the blacks were disfigured by a yellowish or greenish tinge; while many experienced photographers who had sub-

scribed to raise the amount demanded for the publication of the secret, complained that, after following most carefully the inventor's published directions and using his own paper, their efforts had resulted only in repeated failures. While this article is going through the press, however, the Editor learns that the difficulties and uncertainty attending the process have been overcome by an amateur photographer, Mr. W. BLAIR of Perth, who observed that the greater part of the black compound lay on the surface of the paper, without penetrating it, thereby preventing the light which passed through the negative from reaching the paper; and what did reach the paper acted with greater or less effect at different points, according to the varying thickness of the carbon coating, which it is impossible to spread with the brush with absolute regularity. On thinking over this matter it occurred to him, that to get a good picture with anything like certainty and ease, the process must in some way be reversed, and that the carbon must be *lighted* or *sunned* from the other side, that is, on the side *next the paper*; and that the only way to do this was to use thin paper, and turn the back or white side of it to the negative. Having found by experiment, also, that something must be laid on the paper besides the very soluble gum, to prevent the carbon from being removed in the final washing, and conceiving that albumen possessed the desired property, he tried the *reversed* method with MARION'S albumenized thin paper, and found it to succeed perfectly, yielding, with full sunshine and an exposure of one or two hours, prints which are pronounced by a high photographic authority to be remarkable for the vigor of the blacks and the purity of the whites. The blacks, says Mr. SUTTON, precisely resemble those of an engraving, being entirely devoid of gloss, free from the greenish yellow tinge observable in Mr. POUNCY'S prints, and reminding one of black cloth. If the process, on further trial, shall continue to deserve these commendations, it will be creditable to Mr. BLAIR, that, unlike many photographers, he has given his secret to the world gratuitously: for carbon printing, on account of the absolute permanence which it ensures—a quality which has long been the great desideratum in photography—must ultimately, if carried to high perfection, supersede all other processes.

Uranium Printing.—In this process a sheet of paper is immersed in a saturated solution of nitrate of uranium, and dried in the dark. It is then exposed under a negative to sunshine for a few minutes. Where the light acts, the uranic salt is reduced, and a faint positive picture obtained. This is intensified to a deep purple tint by immersing the paper in a solution of chloride of gold; strength, half a grain to the ounce of distilled water. After which it is well washed in water, dried, and the print is finished.

Ink Printing.—By means of this process, positive prints may be obtained in common writing ink. A sheet of paper is immersed in a nearly saturated solution of bichromate of potassa, and dried. It is then exposed under a negative to sunshine for a few minutes. Where the light acts the bichromate is reduced, and a brown positive upon a yellow ground obtained. This is well

washed in many changes of water, and the yellow bichromate thereby removed. The print is now fixed, and is of a pale brown tint upon a white ground. It is intensified by being immersed for a few minutes in a solution of protosulphate of iron, five grains to the ounce; then washed in several changes of water; and, lastly, immersed in a moderately strong solution of tannic acid. The ferruginous salt, which adheres only to the image, is thereby converted into tannate of iron, or common writing ink.

The Silver Printing Processes.—There are two different methods of printing with the salts of silver—one called sun printing, in which the print is produced in its full intensity by exposing a sensitive paper to light under a negative; the other, called development printing, in which a faint image, obtained by the direct action of light, is intensified by a process of development.

In sun printing, the paper may be either plain or albumenized; but as the methods of toning the print are different in the two cases, they must be described separately.

Sun Printing upon Plain Paper.—Dissolve, with the aid of heat, four grains of gelatin and four grains of common salt to the ounce of filtered rain water. When cold strain it through a fine muslin into a shallow dish larger than the sheet of paper to be printed upon. Use the best Saxe paper, and float the face of it for a couple of minutes upon the above solution. Hang it up by one corner to dry. When dry lay it upon a board, and brush over it a solution of ammonio-nitrate of silver, made thus:—Dissolve fifty grains of nitrate of silver to the ounce of distilled water, and add liquor ammoniac to the solution, drop by drop, until the brown turbidity, which is at first formed, is entirely redissolved, and the liquid rendered again clear and colorless. This turbidity is due to oxide of silver which is at first thrown down, and then redissolved by the addition of more ammonia. The best kind of brush to employ is what is called a Buckle's brush, made by pushing a tuft of cotton wool into the open end of a glass tube. The paper should be brushed, first longitudinally, then transversely, and after being left to imbibe for two or three minutes, it should be brushed again, then hung up to dry. As soon as it is dry—for it would turn brown by keeping—it should be exposed to light under the negative until it is rather deeply printed, then taken from the pressure frame, well washed in rain water, then in water to which a few drops of ammonia are added, afterwards in water again. The picture is now a deep slate color, and still sensitive to light.

The next process is to tone it, that is, to substitute gold or oxide of gold, for the silver, which forms the shadows of the picture. This is done by immersing the print for two or three minutes in the following solution:—

Distilled water,	2 ounces.
Hyposulphite of gold and soda,	1 grain.
Pure hydrochloric acid,	5 minims.

In this bath the tint of the shadows changes to a deep purple, and the lights sometimes become slightly yellower. While in the toning-bath the changes of color may be watched by feeble diffused daylight. The

print must then be washed in several changes of water, until all traces of acidity are removed, and fixed by immersion in a solution of one part of hyposulphite of soda to twenty parts of water. In this it should remain about twenty minutes, and the solution should then be thrown away, and the print well washed and soaked in water, many times changed during some hours, after which it is dried. The print is then finished.

Sun Printing upon Albumenized Paper.—A mixture of equal parts of albumen and water, to every fluid ounce of which six grains of salt are added, must be beaten up to a froth, and allowed to settle. Filter the clear liquid through two layers of damped muslin into a shallow dish, and float the sheet of paper—Canson's or Marion's—upon it for a minute, then hang it up to dry. When exsiccated excite it by floating it upon a solution of nitrate of silver, containing forty grains to the ounce of distilled water. Hang it up to dry. The paper should be exposed under the negative until the print is darker than it is intended to be ultimately. On removal from the pressure frame put the print into the following solution:—One part hyposulphite of soda to six parts of water, to every ounce of which half a grain of chloride of gold is added. Leave it in the solution until the red tint which it at first assumes has deepened considerably. Then remove it, wash it in several changes of water, and let it soak for several hours; desiccate it, and it is finished.

Printing by Development.—HOLLINGWORTH'S thin paper is to be preferred to any other. Immerse it in a solution containing six grains of salt and one part of iodide of potassium to the ounce of rain water. When dry, brush over it, precisely as in the ammonio-nitrate process, the following solution of nitrate of silver:—

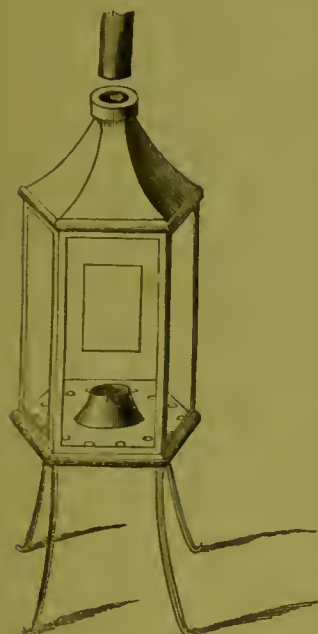
Distilled water,	1 ounce.
Nitrate of silver,	30 grains.
Lemon juice,	6 drops.

Expose in the pressure frame until a faint image is produced; this will require a few seconds only. Then turn up the edges of the paper so as to form the print into a tray; place it upon a perfectly horizontal sheet of glass, and pour into it a small quantity of a saturated solution of gallic acid, which spread quickly over all parts of the print with a bent glass rod. The image immediately begins to intensify. At first it comes out of a fiery red tint, which ultimately passes to a black. As soon as it is sufficiently developed, wash it in two or three changes of water, and fix it by the same treatment as that described in the ammonio-nitrate process; but gold toning is unnecessary. Prints produced by this, or by the ammonio-nitrate process with gold toning, are permanent. Those printed by the albumenized paper process frequently fade.

Before closing this part of the subject, it may be mentioned that the light of the sun is not directly essential to the production of pictures, the light of the moon and stars being sufficient to give an impression of those bodies—a fact highly interesting to astronomers. Considerable condensation of the light is required, and also a lengthened exposure. With the exception of the mechanical adaptations for throwing the light on the sensitive plate, and retaining the image on the same

part during the necessary time, the operations are the same as in ordinary photographic practice. A

Fig. 413.



method has recently been invented by Mr. JOHN MOULE of London for taking positive photographs by means of artificial light, and which is reported to be quite satisfactory. The author has given the method the title *Photogenic*, and the apparatus suited for the purpose he calls the *Photogen*. The latter is a kind of lamp, hexagonal in form, and supported upon a stand of suitable height. The base, frame, dome, and chimney are of galvanized iron, and the sides of glass. In the bottom, as shown in the sketch—Fig. 413—are a number of holes to admit air, and a pan is fixed in the centre, wherein the combustibles for yielding the artificial light are consumed. The composition which the inventor uses is—

Pure saltpetre—nitrate of potassa,.....	112 parts.
Flowers of sulphur,	42 "
Black antimony—sulphide,.....	12 "

It is said that the light emitted by the combustion of this matter is highly charged with the actinic rays that effect the decomposition of the photographic agents, and that the portraits which are taken by it leave nothing to be desired. A square of blue glass introduced between the light and the sitter protects the latter from the glare, at the same time that it does not weaken the effect in the camera. All the other operations are the same as when taking portraits in the sunlight. It is needless to say that the invention, when it becomes more known, will be a great acquisition to photographers and amateurs generally, as it will place them beyond dependence upon the changes of the weather in times and seasons.

PHOTO-LITHOGRAPHY.—This is a process of obtaining a lithograph upon stone by means of photography, from which copies may be printed in printers' ink in the usual way. The best method appears to be that which was recently patented in England by Messrs. CUTTING and BRADFORD of Boston, U.S.

They spread a composition of water, one quart; gum arabic, four ounces; sugar, one hundred and sixty grains, and bichromate of potassa, one hundred and sixty grains upon the stone, which must be preserved in the dark until required, and when the coating is dried it may be exposed in the camera a suitable length of time, or it may be covered by the print or picture to be reproduced and exposed to the light. After it is thus *lighted* it is washed with a solution of soap, which removes the coating from

every part, except where the light has operated in rendering the gum and chromium compound insoluble in the menstruum.

It would appear, by the terms of the specification, that an insoluble soap is supposed to be deposited, or produced, on the surface of the stone, but the explanation given by the patentees is very dubious.

The most delicate grades and tints of light and shade may thus be produced upon the stone, true to nature as the photographic picture itself. The stone having been thoroughly washed with clean water and dried, now receives a coating of ink from the roller, which, uniting with the soap already deposited thereon, serves to give additional body to the picture, and shortly after the stone is ready for the printer; the portions which have been protected by the undissolved or *lighted* gum when wet resisting the ink.

Previous to the commencement of the above-described process the stone is to be prepared, and this preparation will vary according to the nature of the picture or subject to be produced. If it be a manuscript, a lithograph, line engraving, or any plan or line drawing without gradations of light or shadow, running the one into the other, a polished surface may be employed. This will not answer, however, so well for portraits, landscapes, and a great variety of other pictures in which the variations of shade blend the one into the other: in such cases it becomes necessary to give the stone a roughened surface, or, in the language of the workman, the stone is *grained*. Into such a surface the chromated solution of gum sinks deeper, and is then removed more or less according as it has been fixed by the light, and thus the required variations of intensity and the gradations of light and shadow are produced. Where a polished stone is employed, the chromated gum lies upon the surface, and it is found that the variations of light and shadow cannot be produced with that nicety necessary to make a perfect graduated picture such as a portrait that shall be easily printed.

The claim of the patentee is simply confined to the use of gum-arabic mixed with sugar, and of soap for removing the unchanged coating, and depositing an insoluble saponaceous film on the stone, that enables the latter to combine with the ink. All the other ingredients may be modified as to quantity at pleasure.

PHOTOGLYPHIC ENGRAVING.—The process thus designated was patented by Mr. FOX TALBOT in April, 1858; it consists in etching, by purely chemical means, a positive photograph printed upon a copper plate.

Plates of steel, copper, or zinc, such as are commonly used by engravers, are employed. Before using a plate its surface should be well cleaned. It should then be rubbed with a linen cloth dipped in a mixture of caustic soda and whiting, in order to remove any remaining trace of greasiness. The plate is then to be rubbed dry with another linen cloth. This process is then to be repeated, after which the plate is in general sufficiently clean.

The sensitive coating for receiving the image, is prepared by adding to about a quarter of an ounce of gelatin, dissolved in eight or ten ounces of water, by the aid of heat, one ounce, by measure, of a saturated solution of bichromate of potassa in water, and straining

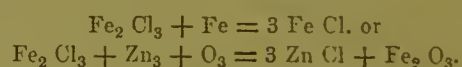
the mixture through a linen cloth. The best sort of gelatin for the purpose is that used by cooks and confectioners, and commonly sold under this name. In default of this, isinglass may be used, but it does not answer so well. Some specimens of isinglass have an acidity which slightly corrodes and injures the metal plates. If this accident occurs, ammonia should be added to the mixture, which will be found to correct it. This mixture of gelatin and bichromate of potassa keeps good for several months, owing to the antiseptic and preserving power of the bichromate. It remains liquid and ready for use at any time during the summer months, but in cold weather it becomes a jelly, and has to be warmed before employing it. It should be kept in a cupboard or dark place. The proportions given above are convenient, but they may be considerably varied without injuring the result. The engraving process should be carried on in a partially darkened room, and is performed as follows:—

A little of the prepared gelatin is poured on the plate to be engraved, which is then held vertically, and the superfluous liquid allowed to drain off at one of the corners. It is then held in a horizontal position over a spirit lamp, which soon dries the gelatin, and the latter is left as a thin film of a pale yellow color, covering the metallic surface, and generally bordered with several narrow bands of prismatic colors. These tints are of use to the operator, by enabling him to judge of the thinness of the film. When it is very thin, the prismatic colors are seen over the whole surface of the plate. Such plates often make excellent engravings; nevertheless, it is perhaps safer to use gelatin films which are a little thicker. Experience alone can guide the operator to the best result. The object to be engraved is then laid on the metal plate, and screwed down upon it in a photographic copying frame. Such objects may be either material substances, as lace, the leaves of plants, *et cetera*, or they may be engravings, writings, photographs, or the like.

The plate bearing the object upon it is then to be placed in the sunshine, for a space of time varying from one to several minutes, according to circumstances; or else it may be placed in common daylight, but of course for a longer time. As in other photographic processes, the judgment of the operator is here called into play, and his experience guides him as to the proper time of exposure. When the frame is withdrawn from the light, and the object removed from the plate, a faint image is seen upon it, the yellow color of the gelatin having turned brown wherever the light has acted. The process, thus far, is similar to one which was patented by TALBOT in 1852. The novelty of the invention consists in the improved method by which the photographic image, obtained in the manner above described, is engraved upon the metal plate. The first improvement dispenses with the operation of washing the plate bearing the copied image in water, or a weak alcoholic solution, in order to dissolve the gelatin from the parts on which the light had not fallen, as recommended in TALBOT's patent of 1852. Instead of this, he immediately spreads over the surface of the plate bearing the picture, carefully and very evenly, a

little finely-powdered gum copal—in default of which common resin may be employed. It is much easier to spread this resinous powder evenly upon the surface of the gelatin, than it is to do so upon the naked surface of a metal plate. The chief error the operator has to guard against, is that of putting on too much of the powder; the best results are obtained by using a very thin layer of it, provided it is uniformly distributed. If too much of the powder is laid on it impedes the action of the etching liquid. When the plate has been thus very thinly powdered with copal, it is held horizontally over a spirit-lamp, in order to melt the gum. This requires a considerable heat. It might be supposed that this heating of the plate after the formation of a delicate photographic image upon it, would disturb and injure the image, but it has no such effect. The melting of the copal is known by its change of color. The plate should then be withdrawn from the lamp and suffered to cool. This process he calls the laying an aquatint ground upon the gelatin, and which he considers a new process. In the common mode of laying an aquatint ground, the resinous particles are laid upon the naked surface of the metal before the engraving is commenced. The gelatin being thus covered with a layer of copal, disseminated uniformly and in minute particles, the etching liquid—sesquichloride of iron—is to be poured on. It is prepared by dissolving sesquioxide of iron, with the aid of heat, in hydrochloric acid. After straining the solution to remove impurities, it is evaporated till it is considerably reduced in volume, and is then poured off into bottles of a convenient capacity. As it cools, it solidifies into a brown semi-crystalline mass. The bottles are then well corked up and kept for use.

This substance, when laid upon a metallic surface of iron, copper, or zinc, attacks these bodies by virtue of its excess of acid, being itself reduced to the state of a protosalt of iron, or if the action be continued with exposure to air, to sesquioxide, thus:—



Hence its use in the present invention.

A bottle—number one—is filled with a saturated solution of sesquichloride of iron in water. A bottle—number two—with a mixture consisting of five or six parts of the saturated solution, and one part of water; and a bottle—number three—with a weaker liquid, consisting of equal parts of water and of the saturated solution. Before employing these solutions to etch the photolythic plate, TALBOT directs that it is necessary to make trial tests of their power, by applying a portion of number two bottle to metallic surfaces prepared as directed, observing, that when the etching goes on too rapidly, a quantity of the saturated liquid in number one bottle should be added to it. On the contrary, if the etching does not commence for a few minutes, or proceeds only slowly, it is a sign that the liquid is too dense, and requires dilution either with water or the contents of the third bottle; either of which ought, however, to be added very sparingly, as a small proportion of either gives great activity to the etching liquid. After the strength and power of the solution have been

determined by three or four such trials, it may be poured on the prepared plate, and spread evenly with a camel-hair brush. The liquid penetrates the gelatin wherever the light has not acted on it, but it refuses to penetrate those parts upon which the light has sufficiently acted. In this way the etching proceeds till all the details of the picture have become visible, and present a satisfactory appearance to the eye, which generally occurs in two or three minutes, the operator stirring the liquid all the time with a camel-hair brush, and thus slightly rubbing the surface of the gelatin, which has a good effect. When it seems likely that the etching will improve no further, it must be stopped. This is done by wiping off the liquid with cotton wool, and then rapidly pouring a stream of cold water over the plate, which carries off all the remainder of it. The plate is then wiped with a clean linen cloth, and rubbed with soft whiting and water to remove the gelatin. The etching is then found to be completed.

Another etching process, very slightly differing from the former, is also recommended. When the plate is ready for etching, pour upon it a small quantity of the liquid number one—saturated solution. This should be allowed to rest upon the plate one or two minutes. It has no very apparent effect, but it acts usefully in hardening the gelatin. It is then poured off from the plate, and a sufficient quantity of solution, number two, is poured on. This effects the etching in the manner before described, and if this appears to be quite satisfactory, nothing further is required to be done. But it often happens that certain faint portions of the engraving, such as distant mountains or buildings in a landscape, refuse to appear, and as the engraving would be imperfect without them, the operator is in that case to take some of the weak liquid, number three, in a small saucer, and without pouring off the liquid, number two, which is etching the picture, to touch with a camel-hair brush, dipped in liquid, number three, those points of the picture where he wishes for an increased effect. This simple process often causes the wished-for details to appear, and that sometimes with great rapidity, so that caution is required in the operator in using this weak solution, especially lest the etching liquid should penetrate to the parts which ought to remain white. But in skilful hands its employment cannot fail to be advantageous, for it brings out soft and faint shadings, which improve the engraving, and which would otherwise probably be lost. Experience is requisite in this as in most other delicate operations connected with photography. The claims of this invention are the etching of the plate without disturbing the coating of gelatin and bichromate of potassa, by washing; the laying of an aquatint of resin or copal upon the surface of the gelatin, after the production of the image, and the application of heat to melt it, and the use and employment of sesquichloride of iron as an etching liquid instead of nitric acid, for the production of photoglyphic engravings.

PHOTOGALVANOGRAPHY.—This process, to which allusion has been made in the historical notice, page 692, consists in obtaining from a photograph, and by means of electro-plating, a metal plate in raised and

sunk parts, from which impressious can be printed in printers' ink.

The positive print—generally on paper—is laid face upwards, on a sheet of glass coated with gelatin, containing bichromate of potassa, and dried; it is then exposed to light in a pressure frame for a few hours. The time of exposure, of course, depends on the intensity of the light. Sunshine is preferred, but is not necessary. The picture on the gelatin is developed in raised and sunk parts by immersion in water. Where the light has *not* acted, the gelatin swells and forms a ridge, or a series of minute granulations, but where it *has* acted, the gelatin is hardened and does not swell. The picture thus formed is very curious, and resembles a positive by reflected light, the shadows and dark parts being rough, and the lights smooth and polished.

A mould of the picture is then taken in gutta-percha, about half an inch thick. This mould is an intaglio picture, precisely resembling the finished copperplate.

A copperplate is made from the gutta-percha mould, by electrolysis. This part of the process is very slow, occupying perhaps a week or two. The copperplate thus obtained is called the matrix. It precisely resembles the original gelatin picture.

The plate from which the proof is to be printed is obtained by the electrotpe process from the matrix. This is a slower process than the last, because the copper is much thicker. It occupies about three or four weeks.

The entire operation, therefore, occupies about six weeks. From the final plate, four or five hundred good impressions may be struck in the ordinary way. A considerable number of plates may be obtained from the matrix; also of matrices from the gutta-percha mould, and of gutta-percha moulds from the gelatin picture. Here, then, are the means of almost indefinite multiplication. The most elaborate subjects may be engraved by this process in as short a time as the simplest; the amount of detail in a photograph or photogalvanograph making no difference—for light, chemistry, and electricity do the work. The time at present required for any subject is a few weeks; the time frequently spent on engravings is two or three years.

THE STEREOSCOPE.—Before closing this article on photography, it may be well to dwell for a short time upon an instrument which creates, as it were, the pictured objects anew, and gives to them all the fulness and solidity which they exhibit in nature. Such is the *stereoscope*; and it may be stated with truth that it has more than doubled the pleasure and gratification derived from the beautiful productions of the photographic art. As a full exposition of the very simple optical principles on which the stereoscope is constructed would occupy more space than can be devoted to it, the Editor will give only the leading facts connected with it, together with brief directions for the taking of portraits or pictures to be seen in this instrument. Every one knows that by its agency two dissimilar pictures, of the same object or group of objects, placed on the same plane at a proper distance, are resolved into one; and that this exhibits all the attributes of the original, such as length, breadth, thickness, and relative distance.

The stereoscope—so named from two Greek words expressing *to see solid*—has given rise to much unpleasant discussion, with reference to the honor of its invention. There can be no doubt that Professor WHEATSTONE constructed the first reflecting stereoscope, and his memoir describing the instrument appears in the *Philosophical Transactions* for 1838, having been read before the Royal Society of London in June of that year. No claimant appears prior to this, and therefore there can be no doubt that to WHEATSTONE belongs the honor of having invented the stereoscope, or an instrument calculated to exhibit two slightly different pictures of the same object in such a manner as to produce the appearance of a single object, or group of objects, invested with the attribute of *solidity*. Sir DAVID BREWSTER, however, in the latest edition of his *Optics*, not only claims for himself the merit, to which he is justly entitled, of having invented the first really useful form of the *lenticular* stereoscope in 1844, but even prefers the claim of Mr. ELLIOT, an Edinburgh mathematician, to that of Professor WHEATSTONE, as the original inventor of the instrument. In the *Cosmos* for June, 1856, the latter distinguished philosopher indignantly confutes this statement, and cites Mr. ELLIOT's own admission, that in claiming priority of invention he labored under a mistake as to dates; having thought that a republication of WHEATSTONE's memoir which appeared in the *Philosophical Magazine* for April, 1852, was the first and original account of an instrument which had been recently invented. It appears, however, that Mr. ELLIOT is really entitled to the merit of having constructed a kind of lenticular stereoscope so early as in 1839; and the only question which remains unsettled is the claim of Professor WHEATSTONE to the prior invention of this form of the instrument also—a claim which he rests on certain expressions in a letter received from Sir DAVID BREWSTER himself. But the reader who desires fuller information on this subject is referred to the eighth volume of the *Cosmos*, and without entering further into the question of these conflicting claims, it may be stated as a fact beyond doubt that to Sir DAVID BREWSTER belongs the honour of having, in 1844, invented a lenticular stereoscope which, in convenience and portability, far excelled any other form of the instrument previously known, and first brought it into general use—an instrument which soon became very popular, and still contributes to the pleasure and gratification of thousands. Messrs. KNIGHT of London have, within the last few years, patented a new form of stereoscope, similar to BREWSTER's however, excepting the eye-tubes, which are dispensed with; their place being supplied either by a plano-concave and plano-convex lens of the same focal length, fixed to one another by their plane sides, or by prismatic ones.

The construction of the stereoscope is founded upon the faculty of binocular vision, or that property by which only one object is seen, notwithstanding that the form of it is depicted on the retina of each eye. On looking at any object it is evident that more of it is seen with the right eye on the right side than with the left, and equally the left eye observes more on the left side

than the right. Hence the picture presented to the right eye is slightly different from the view which the left takes of the same object; but by looking with both eyes all the parts noticed in the two monocular views are visible, and the pictures presented to both appear to each in the same spot, or overlap each other, so that only one object is seen, but a view of it slightly different from that which would be taken by one eye. It is partly owing to this circumstance, and partly in consequence of the greater or less convergence of the rays from the different points of an object in proportion as they are nearer or more distant, that the idea of solidity is realized; and this explains the cause of the difference observed between a picture of a bust or statue and the original, or of a landscape painting, and that which it represents.

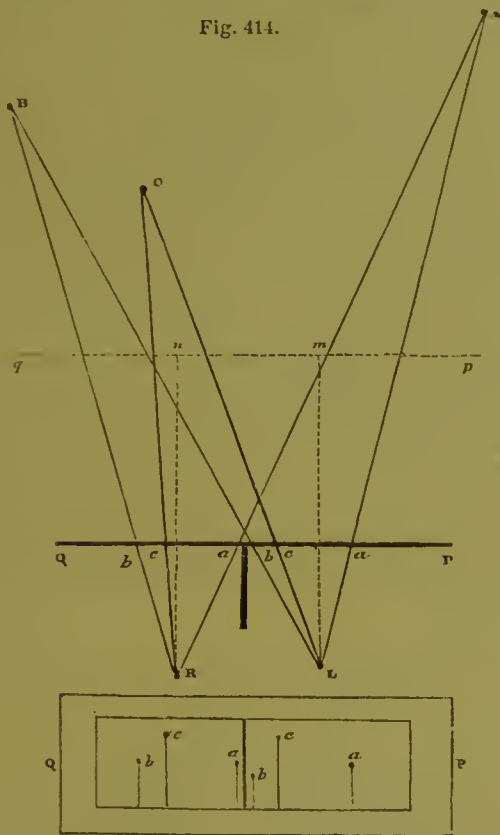
On these simple facts the stereoscope was founded, it being considered that by representing two pictures of the same object exactly corresponding to those which would be formed on the retina of each eye, the head remaining stationary, a means of converging them into one, so that they might have the appearance exhibited by them in nature, could be devised. The difficulty of producing two such pictures had been a drawback to the project; and it was not till photography had obviated this inconvenience, by producing pictures of the object corresponding to those which the right and left eye respectively take of it from a given point, that its value was fully appreciated. On looking at the stereoscopic pictures singly with both eyes, no appreciable estimate of solidity or distance can be formed. If, however, the observer could contrive so to converge the optical axes as to throw the two pictures into one, then, indeed, all the solidity possessed by the originals would appear. It is needless to say, however, that very few are capable of doing this; and, when effected, it is with much pain to the eyes. But this, which is so difficult with the unaided eye, is what the stereoscope accomplishes—that is to say, it brings the corresponding points in each picture together, and, by their coincidence, gives the appearance of solidity and distance to them, just as in natural vision the binocular pictures are resolved into one view, leaving the impression of one or a series of objects, as the case may be, having length, depth, and breadth.

To simplify this a little more, if two stereoscopic pictures of the same object be mounted, so that the distance from their centres shall be equal to that between the pupils of the human eyes, and placed at one end of a box eighteen inches long, divided by a partition, and having two holes in the other end to correspond with the eyes of the observer; on illuminating the pictures only one will be discerned in consequence of the rays from each being refracted, first from the pupil of each eye at a slight angle to the retina, and thence in a straight line till the two lines meet or converge, at which point not two, but one picture will be seen, but this one will exhibit all the details of solidity and relative distance. Such was the instrument contrived by ELLIOTT; but the distance from the eyes at which it was necessary to place the pictures to bring them to coincide, is reduced by the use of reflectors or lenses, as in the instruments of WHEATSTONE, BREWSTER, and others.

Mr. SUTTON gives the following explanation of the principle of the stereoscope:—

Let L, R—Fig. 414—be the eyes of a spectator; A, B, C, lamp-posts of different heights, having lights, or luminous points, A, B, C, at the top. Draw the visual rays,

Fig. 414.



LA, LC, LB, RA, RC, RB. Cut them by a vertical plane, PQ, parallel to the line which joins L and R. Then the points *a, b, c*, where the visual rays pass through this plane will be the images of A, B, C, as seen from the stations L and R, PQ being supposed to be the plane of a perspective picture. If the plane, PQ, be placed as shown in the figure, so that the perspective view as seen from L may be completely exterior to that seen from R, the pictures will be as represented on a card beneath L and R in the lower part of the figure.

Now, if the perpendicular distance between L and the plane PQ be such that the points *a, b, c* can be distinctly seen by an eye at L; that is to say, if this perpendicular distance be not too short for distinct vision, and if the card, PQ, be placed before the eyes, as in the figure, the right picture being cut off from the left eye and the left picture from the right eye by a partition, as shown, then instead of seeing two pictures, *abe, abe*, only one image will be seen, and that one image will appear to be the lights, A, B, C, in their natural position, and at their true distance. For when the left eye is directed to *a* along the line La, the right eye is directed to *a* along the line Ra, and the optic axes La, Ra, would meet at A, so that the spectator, instead of seeing two images, *a, a*, upon a plane, PQ, sees one image, A, at the true distance and in the true position of the light, A. Similarly with respect to the other images, *b, c, b, c*, which combine and produce single images apparently at B and C.

It is evident that the perpendicular distance of PQ from L or R, which call F, will depend upon the size of the angle, ALB or ARB; for the smaller that angle is, the farther the plane, PQ, may be placed from L and R, and therefore the more easy it will become for the images *a, b, c*, to be seen distinctly by persons of ordinary vision. Most persons can see a thing distinctly at a distance of eight inches. If then $F = 8$, the angle ALB may be about 16° .

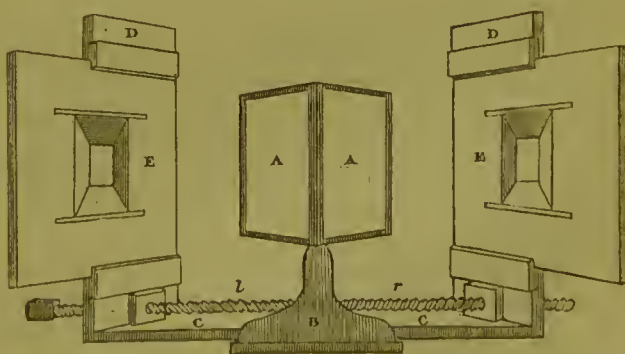
Now suppose that at each of the stations, L, R, a photographic camera is placed, the lens of which is eight inches focus, and adjusting these cameras with their axes strictly parallel, take the pictures of A, B, C, including an angle of 16° . Then when these pictures are properly mounted they will be identical with the perspective views of A, B, C, upon the plane PQ; and if placed in a box having a partition in the middle and holes to look through at P and Q at a distance of eight inches from the pictures, the spectator on looking through the holes will perceive a single image of the points, A, B, C, at their true distance, and in their true relative positions.

A box so constructed may be called a *simple stereoscope*, because it does not involve the use either of lenses or reflectors, and the pictures properly taken and viewed in it have the inexpressible charm of truthfulness.

Of what use then, it may be asked, are lenses and reflectors? In the first place, the simple stereoscope, when adapted to persons of ordinary sight, does not include an angular field of more than 16° ; which is in general too small. A photographic picture should include at least an angular field of from 25° to 30° . This can only be effected by bringing the pictures as near to the eyes as five inches, at which distance most persons find a difficulty in seeing them distinctly; but this difficulty is overcome by placing a *whole* lens of five inches focus in each of the holes L, R, and viewing the pictures—which must be taken with a lens of five inches focus—through them.

Reflecting Stereoscope.—Fig. 415 represents the stereoscope of WHEATSTONE. It consists of two plane mirrors, AA, so adjusted as to form an angle of 90° with each other. They are fixed by their common edge against an upright, B, in such a way as to reflect the images placed in the side-frames, EF, fixed on the

Fig. 415

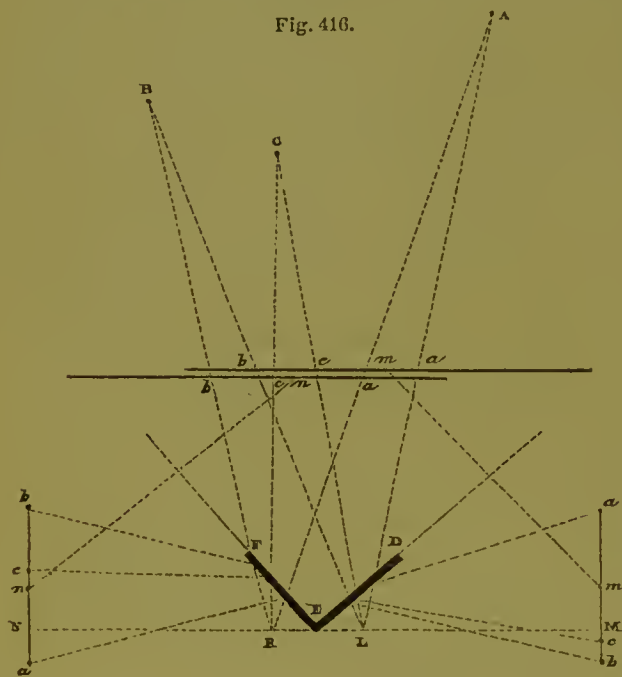


upright boards, DD. The latter are attached to the sliding-boards, CC, movable from either end by the wooden screw, lr, formed with a right and left hand thread for that purpose.

To see the pictures by this instrument, the observer

must stand before the mirrors, having the right and left eye respectively before the right and left hand mirror; then, on moving the frames EE , by the screw rl , backwards or forwards, the reflected images will be made to coincide at the optic axes and produce a single image of the same apparent magnitude as that observed. When properly executed pictures—such as are taken in a binocular camera, and which are seen with the same inclination of the optic axes—are introduced, the instrument may be simplified by omitting the screw and movable boards, the side ones being fixed in their proper places.

Mr. SUTTON, discussing the subject of the reflecting stereoscope, says:—Referring again to Fig. 414: if the visual rays are cut by a plane, $p q$, instead of $P Q$, the



pictures will be larger than before, and instead of being entirely exterior one to another, will overlap, and be, as it were, mixed together. But if the pictures be taken in cameras placed at L and R , with lenses of focal lengths Lm or Rn , having their axes parallel, and then by means of reflectors the images of the pictures so taken be thrown into their proper positions on the plane, $p q$, and these images viewed by eyes at L and R , a truthful solid image will be produced, as in the former case; because the left eye will not then see the picture from the right station, nor the right eye that from the left station. The principle of this arrangement is exhibited in Fig. 416, where DE , EF are the reflectors placed at right angles to each other, and ab , ba the pictures at right angles to the dotted line, or base, mn , passing through the point E , the distance of the reflectors from that angular point being equal to Lm or Rn , and therefore to the focal length of the lens with which the pictures are taken. The distance of the middle points, mn , of the pictures from the dotted base, is half the distance LR . The pictures are taken in a nonreversing slide, so that their images on the plane $p q$, as seen in the reflectors, are not reversed; this is an important point to attend to. The image of the left hand picture is amb ; that of the right hand

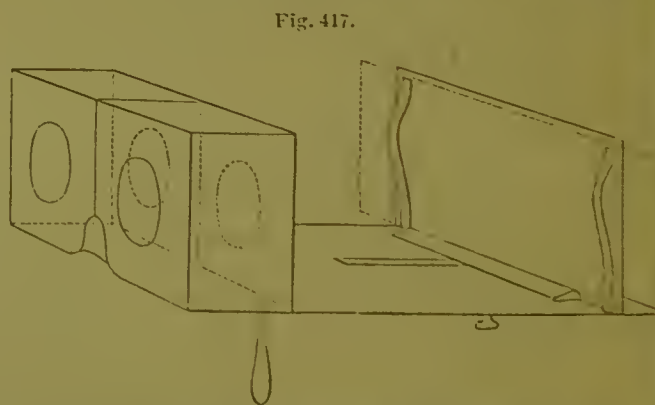
picture bna , the lines, pb , qa , being separated for the sake of distinctness, but in point of fact the images lie on the same plane. The left eye cannot of course see the image of the right picture, and *vice versa*, so that the images overlapping produce no confusion. The image of each picture and the picture itself are symmetrically situated with respect to the reflector by which it is viewed.

All this being understood, the mode in which the instrument acts will now be intelligible. A pencil from b in the left picture, after reflection at the left mirror, DE , enters the left eye as if it had come from the point b on the line pb ; the point, b , is therefore seen by the left eye in the direction Lb . Similarly, a pencil from b in the right picture, after reflection at the right mirror, FE , enters the right eye as if it had come from the point b on the line qb ; the point b is therefore seen by the right eye in the direction Rb . These two lines, Rb , Lb , are the instantaneous directions of the optic axes, and being produced they meet at B , which is the true position of the object, B . Similarly with respect to the other objects, A , C . Therefore by means of the reflecting stereoscope a true representation is afforded in natural relief and actual distance of the objects in the picture.

The reflecting stereoscope is not open to any single practical or theoretical objection. As an optical instrument it is *absolutely perfect*, being subject to no defects of distortion or aberration. For any scientific purpose, therefore, the reflecting stereoscope should always be preferred to the other. The reflectors may be made of polished speculum metal if objection be raised to glass mirrors, and the pictures may be taken simultaneously in a camera with double lenses two and a half inches from centre to centre.

The Lenticular Stereoscope.—The best construction of this instrument for exhibiting paper positives is shown in Fig. 417, which scarcely needs explanation.

The *whole* lenses fixed in the front of the box are placed two and a half inches from centre to centre, and should not be less than one inch in diameter. They should be five inches focus, and achromatized meniscus lenses with the hollow side outwards; in fact the same lenses as those used for taking the pictures, which may



be unscrewed from the camera, and screwed to the stereoscope. The back of the solid box should have holes in it as represented by the dotted lines, and also a partition in the middle. The orifices should be two and a half inches from centre to centre, and their dia-

meter determined by trial—generally about one inch. The inside of the front box should be properly blackened. The picture may be either square or circular, mounted two and a half inches from centre to centre, and about two and one-fourth inches in diameter. By the centre of each picture is meant the point where the axis of the lens cuts it.

Brewster's Stereoscope.—The stereoscope, modified by Sir DAVID BREWSTER, is shown in its most popular form in Fig. 418. It is a box having an aperture at the bottom, but most generally at the front, as seen in the drawing; an aperture at the side allows the slide bearing the pictures to be introduced. In the two brass tubes, R, L, half or quarter lenses are fixed, so that their curved circumferences will be inwards, or nearest one another, for the purpose of aiding the eyes in bringing the pictures, or representation of them, to coincide at the point of convergence of the visual axes. The tubes are made to slide up and down to suit the focal lengths of different eyes. By adjusting the lenses, the observer, on looking through both, sees only one picture midway between the two, and exhibiting the object or objects in bold life-like relief. It is

Fig. 418.

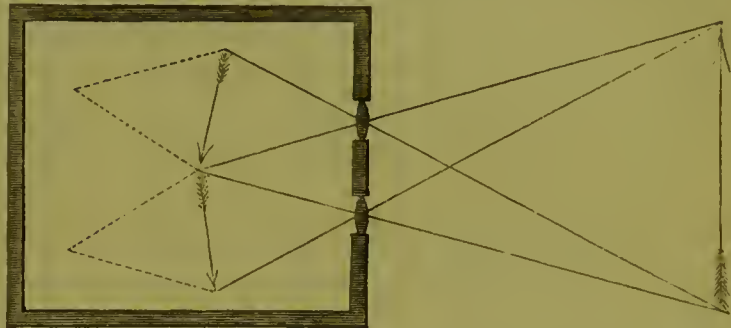


necessary to have the central points of the pictures within two and a half inches of one another, as also the tubes, in order to correspond with the position of the eyes.

Stereoscopic Pictures.—To obtain two pictures in their proper position for the stereoscope by means of one camera, it is evident that the instrument must have two apertures, and that these must correspond to the position of the eyes. The stereoscopic camera is constructed on this principle, with two lenses in front, of the same focal length, two and a half inches apart, focussing glass, and other requisites, as in the ordinary instrument. BREWSTER, however, contends that exact pictures of natural objects cannot be taken by the cameras in general use, in consequence of the lenses being too large, and causing a distortion in all the lines and portions of the object which do not fall in

the centre of the picture. He further states that it is almost impossible to take true stereoscopic portraits with a single-lensed camera, owing to the difficulty of measuring the proper angle at which the two should be taken, and of the sitter maintaining the same expression. Instead of employing two lenses, he bisects one,

Fig. 419.



and employs the half in each aperture, with the view of obtaining better results; for, as he says, it is impossible to grind or polish two lenses, whether single or achromatic, of exactly the same focal length, even when the same glass is used for both the sections. To overcome this difficulty, the single lens must be bisected and ground to a circular form, and afterwards placed in the camera with their diameters of bisection parallel to one another as in Fig. 419.

When portraits or views are to be taken in the monocular camera for the stereoscope, WHEATSTONE makes the position of the camera dependent, not upon the distance of the object from it, but upon the distance at which the pictures are observed in the stereoscope. Thus, when they are to be viewed at a distance of eight inches, he directs that the two pictures should be taken at an angle of 18° ; that is, if the object be the centre of the circle of which its distance from the camera forms the radius, the pictures must be taken from points on this circle 18° apart. BREWSTER, on the other hand deduces the angle at which the portraits or views should be taken from the distance of the subject, and the angle which the distance between the eyes subtends at that distance. This angle he finds by the formula—

$$\text{Tang. } \frac{1}{2} A = \frac{\frac{1}{2} d}{D} = \frac{1.25}{D}$$

d being the distance between the eyes; D the distance of the sitter, and A the angle which that between the eyes—two and a half inches—subtends. By this he finds the angle formed by the two directions of the camera, when the distance of the object from it is that specified, to be as follows:—

Feet.	Degrees.
1.....	11.54
2.....	5.58
3.....	3.59
4.....	2.59
5.....	2.23
6.....	1.59
7.....	1.42
8.....	1.30
9.....	1.20
10.....	1.12

When the distance of the subject from the camera is

one hundred feet, the latter should be placed at points in the circle of which this is radius four feet distant from one another; for one hundred and fifty, six feet, and so on.

To pursue the subject of the stereoscope through all its details, as exhibited in the tubular reflecting, the single and double reflecting stereoscopes, the opera-glass, reading stereoscopes, *et cetera*, is incompatible with the limits of this work; the student who may desire further acquaintance with the subject is referred to BREWSTER on the Stereoscope, or any of the works on optical science which are to be found in libraries. The following remarks will not be out of place:—

In printing stereoscopic pictures from a negative, taken in a double-lens camera by contact in the pressure frame, it must be borne in mind that the print requires to be cut in half and the pictures transposed, in order to bring the picture that was taken from the left station before the left eye in the stereoscope, and *vice versa*. If this be not attended to, a pseudoscopic effect is produced.

In printing stereoscopic transparencies by means of a lens, the following plan may be adopted:—A copying camera, rather more than double the length of the stereoscopic camera, is provided, and the lenses of the stereoscope are fixed in the middle of it. There must also be a partition dividing the camera in half lengthwise. In this way the left lens copies the left picture, at the same time that the right does the opposite. The negative must be placed with its back next to the lenses at one end of the box, and the sensitive positive plate in a common slide at the other end. The camera is then directed towards the sky, and the wet collodion process employed. An exposure of a few seconds is sufficient. The positive need not be divided and the pictures transposed; for, when placed in the stereoscope with its plane side next to the lenses, and a ground glass laid against the film, the pictures are in their right position to be viewed. By putting the lenses midway between the negative and positive, the positive becomes of the same size as the negative. The best lenses to employ are portrait ones, with a small stop between the back and front lenses in each.

In the stereoscopes and stereoscopic pictures commonly sold there are the following five serious defects:

1. The pictures are frequently taken in converging cameras, and then mounted upon the same flat surface.

2. The pictures are generally mounted so wide apart, that the most distant objects in each are wider apart than the distance between the centres of the eyes.

3. An attempt is made to obviate the evil produced by the above practice, by using *semi*-lenses in the stereoscope, which displace the images. This of necessity produces distortion, because straight lines are always represented by curves, when the outside part of a lens is used to view objects through, instead of the centre.

4. The displacement of the images is in general so great as to cause the optic axes to converge to points situated within two or three feet from the nose, instead of the true distance of the objects. The effect of this

is to make the solid picture look like a small model of the object, which the spectator could, if he chose, lay his hand upon, or touch with a yard measure.

5. The focal length of the lenses of the stereoscope is in general six inches, while that of the lenses in the camera is only four inches. This makes objects appear much smaller than they do in nature.

To sum up: The common stereoscope and pictures make objects look very near, very small, and distorted. The lenticular stereoscope, represented in Fig. 417, makes them look of their *true* size, at their *true* distance, and without perceptible *distortion*.

In the preceding it has been announced that the object of the stereoscope is to exhibit things precisely as one sees them in natural vision; that is, with eyes two and a half inches apart. But if it be thought desirable for any purpose to represent things as one should see them, were the eyes wider apart than two and a half inches, then the distance between the stations may be exceeded.

Mr. SUTTON of Jersey kindly supplied the Editor with some valuable matter for this monograph.

PLATINUM.—*Platine*, French; *Platin*, German.—Whoever attentively regards the progress of any science, and sympathizes with those whose labors are ardently directed to its development, must, considering the difficulties that have to be overcome, necessarily feel interested in every discovery which tends to give greater certainty to their researches, and enable them to deduce laws for its extension and simplification. On this ground the subject of the present article cannot fail to recommend itself to every chemical student, since to it in a great degree may be attributed the precision observed in the results of every well-conducted analytical research. Although numerous subjects had been investigated before the discovery of platinum, and well-based conclusions drawn from them, still the methods by which these investigations were conducted were most circuitous; and, in the absence of a metal like platinum, the stoichiometrical equivalents of bodies were frequently mere approximations that required to be rectified by more appropriate apparatus and modes of analysis. In the multifarious operations of fusion, solution, evaporation, and weighing, connected with the labors of the chemist, no other substance can bear comparison with platinum. The corrosive agents used, and the unconquerable power of affinity, affected more or less all the utensils which the operator could command previous to the discovery of this metal, so that when the most devoted care was bestowed upon any research the results did not indicate the truth, and could not be depended upon even when they were rectified by an approximate estimation of the amount of the error. It is not so now; for, unlike gold, silver, or porcelain, platinum stands the test of intense heat, and so enables the operator to determine the effects of temperature and chemical action on the most refractory bodies; resists the effects of the strongest acids singly; and from the facility it offers of being forged into every convenient shape—such as basins, crucibles, weights, and the like—it facilitates working in the laboratory to a surprising extent. But it is not to the student or chemical philosopher alone that platinum is

of advantage—the manufacturer likewise is benefited by it; thus, in the distillation of sulphuric acid it can hardly be replaced by any other material, and in the preparation of drugs and extracts nothing safer than platinum can be employed.

This metal is not very abundant, though distributed in small quantities over extensive districts, and in numerous and diverse localities. The first account of it with which Europeans are acquainted is that of ANTONIO D'ULLOA, who observed it in the auriferous sands of South America. This notice was published in 1736; but the savans of this country and of the continent could form no idea of its nature till 1741, when Mr. WOODS, an assayer of Jamaica, sent a portion of the ore to Europe. Among the metallurgists of South America, however, it was long known, and bore the name *platina*, a diminutive of the Spanish name *plata* for silver. This term must have been applied on account of its occurrence in bright polished grains, appearing in color and brilliancy like silver. At that period, however, nothing being known of its properties further than that it possessed great weight, it was regarded as having no value, and, therefore, any quantity which might have been collected was thrown aside as useless—in fact, it was put beyond the reach of the miner, by casting it into the deep rivers, lest they might use it to sophisticate the gold they collected. On this account a large quantity of platinum ore has doubtless been put out of the reach of present or future use for a considerable time to come. WOOD gave the first scientific account of it in a paper published in the *Philosophical Transactions* in 1750; and in 1752 its proportion in the platinum sand was determined by SCHEFFER. LEWIS wrote upon it in 1754; MARGGRAF in 1757; and since then researches upon it have been published by BERGMANN, VON SICKINGEN, MUSSIN-POUSCHKIN, FOURCROY, and VAUQUELIN, WOLLASTON, DESCOTILS, TENNANT, BERZELIUS, EDWARD DAVY, DÖBNER, and CLAUS; from which investigations resulted the discovery of palladium, rhodium, iridium, osmium, and ruthenium in the ore, and all alloyed with platinum.

LOCAL SOURCES.—The principal districts which afford platinum are those of Brazil, Peru in South America, and Antioquia in the North, also the slopes of the Ural Mountains. In Borneo, and in almost all the gold-washing districts throughout the world, traces of the metal have been detected. Along the coast of the South Sea, and on the Western slopes of the Cordilleras of the Andes, between the second and sixth degree of north latitude, platinum occurs; but the most productive washings are those of Condoto in the province of Novita, of Santa Rita or Viroviro, of Santa Lucia, of the ravine of Iro, and Apoto, between Novita and Taddo. The deposit of gold and platinum is found in alluvial ground at a depth of twenty feet; both metals are separated sometimes by picking out the grains of platinum ore, and, when this method cannot be conveniently adopted, by amalgamating the gold, by which process the platinum is left.

In the provinces of Matto Grosso and Minas Geraes in Brazil, platinum is found in the alluvial deposits which

produce gold. The ore of these localities differs from that of Peru, being met with in grains of a globular form, and which exhibit a surface made up of small spheroidal protuberances strongly adhering together, the interstices being clean and even brilliant. None of the magnetic iron ore or small zircons observed in the Peruvian product are observable in it. It is, however, mixed with small radiated or fibrous grains of palladium.

The veins of manganese in the weathered syenite near Santa Rosa de Osos, in the Colombian province of Antioquia, afford platinum; and it has been obtained from the valley of the river Jacky in Saint Domingo. Like the platinum sands of Peru, the product of this district appears in brilliant rounded grains, as if polished by friction. It yields chromium, copper, osmium, iridium, ruthenium, palladium, and probably titanium. The total quantity derived from South America does not exceed eight hundred and fifty pounds annually, a product which is much inferior to the washings in the districts of the Ural Mountains where the metal is found. In 1819 a whitish kind of gold was detected in the mine of Neiwin Körner; but its nature was not ascertained till 1822, when platinum was detected in it. Platinum washings were established in 1824, and since that period considerable quantities are annually produced by them; they are situated on the Western slopes of the chain of mountains, and the ore is met in alluvial deposits partly, and in other localities injected into the greenstone and serpentino rocks. The chief workings are at Nischne-Tagilsk, Goroblagodat—Knschwa—Nischne-Turinsk, where the metal occurs almost without gold; Bogoslawsk in important quantities; also at Slatoust, Werch-Isetsk, Newiansk, and Bilimbajewsk. In most of these washings the platinum ore constitutes from one-four-thousandth to one-fourteen-hundredth of the sand, and contains on an average about seventy per cent. of platinum. That from Goroblagodat yields eighty-eight per cent. Another ore, osmide of iridium, is also met with in small quantity in these districts, yielding on an average two per cent. of platinum.

Platinum is also found in greater or less quantities in other countries; for instance, in the Ratoo Mountains in Borneo, and in the gold sands found on the North of Ava, black magnetic particles are collected which yield twenty per cent. of the metal. The gold sands of the Rhine afford a small percentage of platinum; so also does the palladium from Wilhelm Works on the Hartz. It has been detected in the departments De la Charente and Deux Sevres in France, in Guadalcanal in Spain, and in Ohlápian in Hungary. According to PETTENKOFFER, all silver, unless subjected to a particular process of purification, contains traces of this metal; he found it in the gold reclaimed from the furnace slags of Mnich. GUEYRNARD latterly detected it in the grey copper from the Department des Hautes Alpes, and in the bournonite from Saint Arey on the Mure. RITTERSON observed it in the gold sands of California, and MALLET in the auriferous gleanings from the Wicklow Mountains.

Platinum, though invariably found in the metallic state, has never been discovered pure and unalloyed.

The annexed table exhibits a few analyses of the product from different localities:—

COMPOSITION OF CRUDE PLATINUM ORES.

	Herzellus.				Svanberg.		
	a.	b.	c.	d.	e.	f.	g.
Platinum,	78.94	73.58	86.50	84.20	86.16	84.34	55.44
Palladium,	0.28	0.30	1.10	1.06	0.35	1.66	0.49
Rhodium,	0.86	1.15	1.15	3.46	2.16	3.13	6.86
Iridium,	4.97	2.35	—	1.46	1.09	2.58	27.79
Osmium,	—	—	—	1.03	0.97	0.19	trace
Iron,	11.04	12.98	8.32	5.31	8.03	7.52	4.14
Copper,	0.70	5.20	0.45	0.74	0.40	trace	8.30
Manganese,	—	—	—	—	0.10	0.31	—
Osmium-iridium,	1.96	2.30	1.40	—	1.91	1.56	—
Grains of sand,	—	—	—	0.60	—	—	—
Lime,	—	—	—	0.12	—	—	—
Loss,	1.25	2.14	1.08	1.92	—	—	—
	100.00	100.00	100.00	100.00	101.17	101.29	103.02

The sample *a* in the foregoing table was a dark-grey ore from Nischne-Tagilsk in the Ural, which was non-magnetic; the sample *b*, from the same locality, but magnetic; *c* was from the washings at Goroblagodat in the same region, and perfectly non-magnetic; *d* was obtained from Barbacoas, and consisted of very large grains; *e* was from Choco, an ore freed from ferruginous particles as much as possible with the magnet; *f* from the river Pinto. This variety was classified into several subvarieties; thus, *a*, rounded grains, having considerable lustre and a color inclining to leaden-grey, of specific gravity equal 17.88; *b*, angular grains, of a light grey color and little lustre, of specific gravity 17.08; *c*, rough grains, somewhat yellowish, but having black points, specific gravity 14.24; and *d*, black shining grains, specific gravity 7.99. Of these, the *a* variety was analysed, and the numbers stand under *f* in the table. The results under *g* are of the osmium-iridium from South America.

Generally the ore of platinum is met with, as already stated, in small grains; but considerable masses of the metal have occasionally been discovered. The largest lump that has been found in America is retained in Madrid; it weighs eleven thousand six hundred and forty grains, or two pounds troy, and appears in size nearly equal to a turkey's egg. This specimen was found in 1814 in the gold mine of Condoto. A lesser lump was brought from Choco by HUMBOLDT, and presented to the cabinet of Berlin; it weighs one thousand and eighty-eight grains, or little more than two and a half ounces. Much larger masses of the metal have been found in the Russian territory already mentioned. A nugget of platinum, found at Nischne-Tagilsk, and still retained in the St. Petersburg collection, weighs ten pounds fifty-four zolotnik—9.2364 Prussian pounds weight—but its specific gravity is only 16.0. Another lump of nearly double the size of the former, was discovered in 1830 in the same works; it weighs twenty pounds thirty-four zolotnik Russian—equal to 19.684 pounds avoirdupois; and later, another mass weighing 22.744 pounds was found. In the royal mineral collection of Berlin is a piece of platinum ore which was presented to the cabinet by Count DEMIDOFF.

SCHUBART states that from 1822 to 1835 no less

than thirty-one thousand and seventy-two Prussian pounds of platinum were obtained from the Ural Mountains; in 1836 one hundred and eighteen puds two pounds, and in 1848 one hundred and fourteen puds, equal to three thousand nine hundred and eighty-seven and a half Prussian pounds were obtained.

PREPARATION OF PLATINUM.—When obtained directly from the ore the difficulty of preparing the metal pure increases according to the number of other components associated with it; if the platinum be alloyed only with gold, all that is necessary is to treat it at once with nitro-hydrochloric acid till the whole is dissolved, to remove the excess of acid by evaporation, and then produce the ammonio-chloride of platinum by the addition of chloride of ammonium. The terchloride of gold may be washed out of the yellowish-red crystalline salt by water. If other metals be united with the platinum, as in the samples of which the analyses have been given above, then the sand is alternately treated with strong nitric and hydrochloric acids, till all the copper, iron, lead, and silver, manganese, *et cetera*, are removed; the washed residue is then acted upon with *aqua regia* till the whole of the metals dissolve. A moderately dilute solution of sal-ammoniac is now added to the clear filtered liquid, which should, however, be as free of acid as possible, and the precipitated double salt of ammonia and platinum collected, washed well with cold water, dried, and reduced to the metallic state. The latter operation is effected by gently heating the mass at first, and indeed till the whole of the ammoniacal salt is expelled, and subsequently bringing it to a strong red heat. The residue now will be pure metallic platinum in a very finely-divided condition, or, as it is ordinarily termed, *platinum mohr*—*platinum black*. The rhodium, palladium, osmium, and iridium, provided a little nitric acid be added previous to precipitation, remain in the mother-liquid, and can be recovered subsequently.

The product thus obtained may be again dissolved in *aqua regia*, and reprecipitated as before, when any palladium which might have been thrown down before will be removed in the liquor and washings of the ammonio-platinum salt. The metal obtained by heating to redness the last-mentioned compound, or by

electrical precipitation, by means of a plate of zinc, from an acid solution of the bichloride of platinum, is—after washing and drying, and subsequently heating to redness—in the form of a black slightly adhesive mass, which may be reduced to a powder of the same appearance, capable by pressure and friction of being made to assume the metallic lustre.

PROPERTIES.—In its purity platinum has a white color, nearly approaching to that of silver. Its density is, with the exception of iridium, the greatest of any known body. Several results nearly coinciding have been arrived at regarding its weight, among which are the following:—CLARKE found the specific gravity of hammered platinum to be 20·875; BORDA, 20·98; SICKENGEN, 21·061; WOLLASTON, 21·25; BERZELIUS, 21·45; KLAPROTH, 21·74; and CLOUD, at 62·6°, 23·543. When compressed by welding, and drawn out into thick wire, it indicated 21·4, and after being still further extended, 21·5. It is infusible at the highest temperature of a wind furnace, though capable of being welded like iron at a white heat; the temperature of the oxyhydrogen blowpipe, however, as also that of the flame of a powerful voltaic current, readily melts and even boils it, dispersing a portion into vapor, which appears to burn and form an oxide of the metal. DUMAS observed that it becomes harsh and brittle when heated powerfully in contact with charcoal, owing to its combination with a little carbon, or silica, or phosphorus. Platinum is very malleable, and, therefore, can be beaten out into very thin plates, and drawn into wires one-two-thousandth of an inch in diameter; and with proper means, such as inclosing it within a silver wire, into wire only one-thirty-thousandth of an inch. The least admixture of iridium deprives it of this quality to a greater or less extent. Air and moisture have no effect upon the metal even in the heat; unlike gold and silver, sulphur and mercury do not injure it even when intensely heated. Nitrate of potassa, however, and potassa and lithia, at a high temperature, oxidise it; but it remains uninjured by the strongest simple acids. The combination of hydrochloric and any other of the mineral acids dissolves it readily; so likewise chlorine water, or a mixture of a chloride or nitrate, and of nitric or hydrochloric acid, and in every instance a bichloride— Pt Cl_2 —of the metal results. With phosphorus, arsenic, antimony, bismuth, cadmium, tin, and lead, platinum forms alloys at moderately high temperatures; and if the heat be increased it combines even with silver and copper, in which state it is sometimes readily dissolved by nitric acid, although this has no action upon it in its purity. Platinum is not such a good conductor of heat and electricity as other metals of less density. DESPRETZ has given the following numbers indicative of the comparative conducting power of the metals, assuming that of gold to be equal to one thousand:—

Gold,	1000
Platinum,	981
Silver,	973
Copper,	898
Iron,	374
Zinc,	363
Tin,	304
Lead,	180

WOLLASTON has shown, however, that the above results are untenable, since, according to a simple experiment devised by him, if rods of the several metals of equal length and weight be covered with wax, and equally heated at one end, the wax on the copper rod will have melted at the distance of 3·5 inches, on the silver at 2·5 inches, and on the platinum and palladium only at the distance of an inch. Its expansion is less than any of the other metallic bodies, being only 0·0009918 between 32° and 212°, or one thousand one hundred and eighth of its bulk. Its specific heat, according to DULONG and PETIT, is 0·03414.

Such are the principal properties of forged platinum, or of the metal made into utensils, wire, or thin leaves; but in its other states, such as platinum black and spongy platinum, it exhibits other properties, which are highly interesting and characteristic of this metal.

Spongy platinum is obtained, as already intimated, by heating the ammonio-chloride of platinum to redness; and provided the salt be pure, no other substance will contaminate it. The substance appears of a dull grey color, soft and porous; when ignited strongly it adheres together, and by subjecting it to pressure with hard bodies, it is made into the form of laminae, having the metallic lustre. The interest attached to this body arises from the fact that without any apparent change it induces the combination of gases with one another, or the oxidation of bodies, to a remarkable extent. DÖBEREINER was the first to bring this remarkable fact before the consideration of the scientific world, by showing that a stream of hydrogen and of oxygen gases directed upon it are inflamed merely by its contact, and that hydrogen alone is capable of making it red hot. DULONG and THENARD showed that this metal, in the more compact form of fine wire and foil, is capable of inducing the union of oxygen and hydrogen in a limited degree, and FARADAY has shown what precautions are necessary to be observed to insure success in the trial—namely, cleanliness of the metal effected by fusing potassa on its surface, and after washing in water, rinsing it in hot oil of vitriol, and again with water. In this state platinum foil will act upon a mixture of the two gases in the proportion of one volume of oxygen and two of hydrogen, so as to speedily become red hot. Contact with the skin, a cloth, or mere exposure for a few days divests it in a great degree of this property; so likewise do sulphide of hydrogen, carbonic oxide, and olefiant gases. The explanation given of this remarkable effect is, that it results from the concurring influence of two forces, namely, the self-repulsive energy of similar gaseous particles, and the adhesive attraction exerted between them and the platinum. Each gas, repulsive to itself, and not repelled by the platinum, comes into the most intimate contact with that metal, and both gases are so condensed upon its surface that they are brought within the limits of their mutual attraction, and so combine.

Spongy platinum has, besides the power of causing the ignition of oxygen and hydrogen gases, that of condensing vapors upon its surface and in its pores to a

surprising extent. Thus, when exposed to the air, ordinary freshly-prepared spongy platinum absorbs oxygen gas to the extent of many times its volume, but little or no nitrogen. In this state it induces the combustion or oxidation of several gases of a combustible nature, and also of liquids. Thus it is that hydrogen is burned and oxidised into water, and alcohol into acetic acid. There are several forms of finely-divided platinum, which exhibit greater power of condensation of gases, and so of effecting chemical changes with greater force than spongy platinum. Such is the product resulting from the combustion of bibulous paper which had been saturated with a solution of bichloride of platinum and dried, and that produced by voltaic action in an acid solution of bichloride of platinum by a bar of zinc; but the most remarkable for this effect is the platinum black of LIEBIG. It is prepared by boiling bichloride of platinum solution with an excess of potassa or carbonate of soda, by which the heavy metal is reduced to the state of a proto-compound, and on now pouring alcohol gradually into the solution, a precipitate of a black color falls, which is the compound in question. It is in a finely-divided, and probably in a more amorphous state than any of the other compounds. When this body is well washed and dried, it takes up as much as two hundred and fifty times its volume of oxygen, and if absolute alcohol be dropped upon it in this state ignition immediately takes place. The combustible gases are quickly inflamed by it, and spirits of wine energetically acetified. As with the others, exposure for some time to moist air, ammoniacal vapors, or sulphide of hydrogen gases, destroys in part or wholly its power of effecting these changes; but washing with an acid and water, or heating it to redness, restores its usual properties again. LIEBIG's platinum black, however, when treated with dry ammoniacal gas is rendered red hot, and considerable quantities of the vapors are absorbed.

Platinum is capable, under certain conditions, of uniting with most of the non-metallic elements, and forming combinations that enter into new formations of the binary saline class; and with the metallic bodies in the form of alloys, but which are of little importance. The chemical symbol of platinum is Pt., and its combining weight 99.

METALLURGY OF PLATINUM.—The complex nature of the crude ore of platinum has attracted considerable notice, and has led chemists to publish several methods for its preparation, as well as for the estimation of the associated bodies.

Whatever method is chosen, the crude ore is submitted to a purifying process before the business of extracting the platinum commences. For instance, the gold which may be mixed with the particles of platinum or alloyed with it, is separated usually by adding mercury, and removing the residual matter from the amalgam. Particles of titanate of iron may be abstracted from it by the magnet, or if the ore itself should be partly attracted, the sortment will afford different qualities of ore. At St. Petersburg, where the platinum of all the ore found in the Ural is extracted, the following process is pursued:—Into each of thirty open platinum basins capable of holding eight pounds,

that are ranged on a sand-bath covered by a glazed dome with movable panes, and the whole surmounted by a ventilator which carries off the liberated acid vapor, a certain quantity of the material is introduced, and a mixture composed of three parts of hydrochloric acid 42° Twaddell, and one of nitric at 73° Twaddell, poured upon it. The whole is then heated during eight to ten hours, or till the evolution of red fumes ceases; and after allowing the undissolved matter to subside, the liquid is decanted into a large cylindrical vessel, the residue is washed with water, and the washings added to the first liquor. The undissolved matter is treated with further quantities of acid till the whole becomes soluble, and the liquors commingled in the common receptacle already mentioned. Aqua regia to the amount of from ten to fifteen times the weight of ore operated upon is required, according as the granules of the ore are smaller or larger in bulk. Moderately dilute aqua ammonia is now added to the acid liquor in the glass vessel, when a precipitate occurs, and on its subsidence the supernatant liquor is decanted into other vessels and evaporated to about one-twelfth in glass retorts, embedded in a sand-bath; on allowing this liquor to cool the double chloride of ammonium and iridium crystallizes out in the form of a dark purple powder, which is separated, and the mother-liquor evaporated to dryness in porcelain vessels, the residue calcined and treated anew like fresh ore. The precipitate obtained in the first instance is dried, calcined, and heated to redness for obtaining the metal in a spongy state. In order to agglomerate this sponge, it is pounded in a bronze mortar, the powder passed through a fine sieve, and the product introduced into the mould in which the ingot is to be formed. Here it is compressed with a rammer which is forced in by a coining press, and when reduced to the proper size, it is removed from the mould and baked for thirty-six hours in a porcelain kiln, after which it may be forged with ease, provided the iridium had been separated from it. The ingot of platinum contracts to the extent of one-sixth or one-fifth of its volume during the roasting in the oven. The cost of preparing platinum is estimated to be about twenty-five to twenty-seven shillings per pound in Russia.

WOLLASTON's method, of which the preceding is a modification, is the most perfect, and that best calculated to yield a pure metal. VAUQUELIN struck upon the same, but in its details that of the former is the most complete. For the preparation of the pure metal, the platiniferous grains are treated with aqua regia and chloride of ammonium, as in the preceding case; only, to prevent the solution of the iridium it is necessary to dilute the acids, so that it will remain in the residue. It is well to reduce the strength of the hydrochloric acid with an equal quantity of water, and also that the aqua-fortis and muriatic acid be quite pure. WOLLASTON has indicated that a quantity of hydrochloric acid, equivalent to one hundred and fifty of dry acid, and as much nitric acid as will contain forty parts, is sufficient for the solution of a hundred parts of the platiniferous matter; but as it is best to have an excess of the ore, one hundred and twenty parts of the latter should be employed. The action of the compound acid should

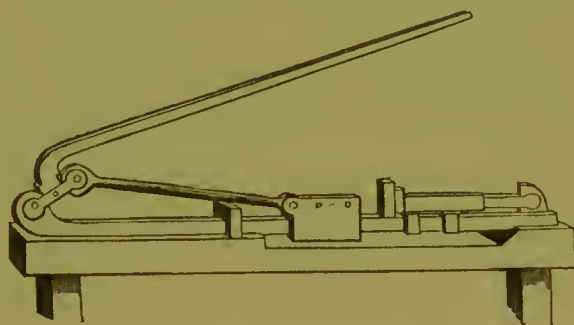
tako placo slowly, and a very gradually increasing temperature be applied till the operation be completed, which happens in about four days. After this the contents of the vessel are allowed to repose, in order that the iridium suspended in small particles in the liquid may deposit; this done the clear solution is to be drawn off, and after the separation of any subsided matter, forty-one parts of chloride of ammonium are added, when the yellow crystalline chloroplatinate of ammonia falls. This precipitate weighs one hundred and sixty-five parts, and contains sixty-six parts of platinum. Palladium, iridium, rhodium, ruthenium, osmium, gold, silver, iron, and any other foreign matters, are all or in part contained in the mother liquor from the last precipitate, together with eleven parts of platinum. To obtain it the whole of the metals are precipitated by means of a clean plate of zinc or of iron, the metallic deposit well washed, redissolved in aqua regia as before, and the platinum thrown down with chloride of ammonium, after having added one part of strong hydrochloric acid to every thirty-two parts of the liquor, with the view of holding the palladium and lead from falling down with the yellow platinum salt. By a later method, WOLLASTON neutralizes the acid solution with carbonate of soda, and precipitates the palladium from the liquid with the cyanide of mercury, in the form of whitish flakes. When this is removed by filtration, the platinum may be removed from the mother-liquor by the addition of forty-one parts of chloride of ammonium.

The precipitate from the first liquor, as well as that from the re-solution of the residuary matter in aqua regia, must be as well washed with cold water as possible, quite free from the chloro-iridate of ammonia; it is then to be dried carefully by pressure between folds of bibulous paper or other absorbent matter. After the whole of the moisture is dispersed, the substance is introduced into a black-lead crucible, and subjected to a temperature merely sufficient to expel the ammoniacal salt and the radical of the platinum compound. Should the heat be raised too high, it would cause the agglutination of the metal, so as to render its subsequent compression into ingots difficult, at the same time that it would decrease its welding power. The loose platinum powder is next rubbed between the palms of the hand very gently, sifted through a linen cloth, and the coarse particles that remain behind reduced in a wooden dish with a pestle of the same material, with as little force as possible. This portion is then sifted like the rest, and the fine powder, which ought not to exhibit any metallic lustre, or the finer parts, may be separated by elutriation and decantation. Having sufficiently reduced the mass, it is mixed with water to a pastelike consistency, and introduced into a brass mould or cylinder 6.75 inches high, 1.12 inch wide at the top, and 1.23 at the bottom, which is inclosed by a steel stopper that enters it to the distance of a quarter of an inch, having the inner face smeared with grease. The whole is now wrapped round with bibulous paper, and placed in a vessel of water so as to fill it with the liquid, when the metal sinks and fills every portion of it equally, and cavities in the ingot are avoided.

A piece of bibulous paper is now laid on the top of

the platinum, and then woollen cloths, and the excess of moisture removed by pressing the contents of the cylinder by a wooden pestle forced by the hand. The cloths and paper are removed at this stage, and a disc of copper substituted, the paste having sufficient consistency to allow the mould to be placed horizontally in a press, to be condensed preparatory to its forging. The kind of apparatus which WOLLASTON invented is represented in Fig. 420. After the pressure is sufficiently exerted, the cylinder is opened, and the ingot, shaped in the form of the cylinder, taken out without

Fig. 420.



danger of breaking in the hands, and heated nearly to redness in a charcoal fire, in order to drive off moisture, burn the grease, and give it greater compactness. It is now laid endwise on a support of clay, which is strewn over with quartz sand, and introduced upon the bars of a wind furnace, but so that it will be two inches and a half above them. A brisk coke fire is to be supplied, and while exposed to the intense heat of the fire the cylinder is covered with a crucible of very refractory clay, but in such a way as not to touch the metal. Twenty minutes' ignition is given, but the intensity of the temperature is moderated during the last few minutes. The defect of blistering so frequently observed in platinum arises from improper treatment of the metal at this stage, and to remedy it the highest possible heat of a wind furnace should be applied. Whilst still red hot the ingot is taken from the furnace, placed upon the anvil endwise, and struck with a hammer repeatedly. Should it bend under this treatment, it must not be straightened by striking it in a horizontal position, but the blows must be directed on the edges as to rectify the bend, and so still preserve it straight. After the ingot is sufficiently condensed by this means, it is in a position to bear forging and working into any desired shape, like any other metal. To separate the ferruginous scales with which it may become coated during its exposure in the furnace, the ingot must be coated with a mixture of equal parts of borax and cream of tartar, in a moist state; placed upon a platinum support; a refractory crucible inverted upon it, without touching; and then introduced into the furnace, and there brought to a full red heat. It is next withdrawn, and immersed in a bath of dilute sulphuric acid, which has the effect of dissolving the incrustated flux and any adhering iron. The ingot may now be hammered out into foil or drawn into wire as required. WOLLASTON found the specific gravity of the metallic powder

compressed in the mould to be 10·0, after strong ignition 17·0 to 17·7, after hammering 21·25, when drawn into thick wire 21·4, and into fine wire 21·5.

The manner of manufacturing crucibles and such vessels designed for chemical purposes, is to introduce the powder platinum into a steel mortar of the intended shape of the crucible, and then the stamp is forced in by means of a press or by repeated blows of a hammer. On removing the steel base of the mortar, the cylinder of platinum may be forced out by carefully pressing the stamp further inwards. The cylinder is then carefully ignited in a platinum crucible, at first in an ordinary assay or air furnace, and afterwards in a blast one to the highest degree, after which it may be beaten on the anvil.

The following directions for mending platinum vessels in use in the laboratory may not be uninteresting. An injured platinum vessel may be mended in the following manner:—The cracked or perforated vessel is thoroughly cleansed, either by fusing potassa in it, and then treating it with an acid, or by scraping the part and afterwards filing down the asperity of the surface; a clean piece of foil of a thickness suited to the vessel is then laid on the defective part, and the whole heated to bright redness in a smith's forge, after which the article is removed to the anvil as quickly as possible, and while yet red hot, struck quickly with a hammer to weld the piece to the body of the vessel. After the adhesion of the two, the part may be beaten out after successive heatings, to give it a smooth surface. To renovate a crack on the edge of a crucible, a narrow bent strip of platinum foil is suspended over it, and pressed as near as possible to the side of the vessel; the whole being then heated in the flame of a blowpipe lamp to whiteness, and while in this state struck on the pointed end of the anvil lightly, but quickly, with the hammer. The part may be smoothened by repeating the heating, and striking it whilst hot on the anvil. When the injury is in the form of a perforation, a platinum wire is selected of the size of the hole and struck flat at its end; this is then passed through the vessel, cut off close at the other side, and the end flattened by a few strokes of the hammer. The vessel is now heated in the fire till it becomes nearly white hot, and struck in the manner directed above, when a secure welding takes place. Should the hole be large, a piece of platinum plate of the suitable size is taken and secured to the edge of the vessel by a number of platinum rivets; it is then transferred to the fire, and when sufficiently heated beaten on the anvil with the flat smooth hammer. In either of these cases the new joint is indiscernible when properly effected.

Platinum crucibles and vessels are liable to injury from the following agents:—Nitrohydrochloric acid, chlorine water, a mixture of hydrochloric acid with chromic acid or its salts, or with a peroxide, such as manganese, attack the metal and readily dissolve it. Lead, bismuth, zinc, or any other metal heated in a platinum vessel to its melting point, or nearly to that degree, alloys itself with the platinum, and either produces a hole at once or an alloy, which is acted upon by acids. The most destructive of this class are those of arsenic and antimony; and hence, not only must the

operator carefully avoid heating these to redness in a platinum vessel, but likewise their oxides and the salts which they form with other bases. This is more especially the case, if charcoal or any carbonaceous matter be present that would cause a reduction of the arsenical or stibic compound. Many other oxides of an easily reducible nature injure crucibles when carbonaceous matters are not carefully excluded. This also applies to phosphoric acid and its salts, since in contact with carbon at a high heat reduction takes place, and a brittle and easily fusible phosphide of platinum results. Alkaline sulphides or cyanides should not be fused in platinum vessels, as these agents dissolve considerable quantities of the metal. Silicium at a high heat unites with platinum, rendering it brittle and disposed to crack; hence vessels of this metal ought never to be heated exposed in an open fire; they should be protected by an outer earthen crucible, contact of the two being prevented by calcined magnesia. Potassa, soda, lithia, and their nitrates, when fused in a platinum vessel, oxidise part of the metal, which is dissolved in the form of an alkaline platinate. This is more particularly the case with lithia. Sulphur does not affect it unless arsenic or some other deleterious body be present, neither has pure phosphoric acid any action upon it.

The purity of platinum vessels is tested by treating them with the simple acids—hydrochloric and nitric—in succession, and examining the acid liquor to ascertain the nature of the dissolved matter, should any exist. It frequently happens that platinum vessels in frequent use in the laboratory get tarnished, in which case they may be again rendered bright and clean by smearing over their surface a paste made with equal parts of pounded borax and cream of tartar—bitartrate of potassa—and fusing it in the heat. On immersing the vessel subsequently in a bath of pure dilute sulphuric acid, all extraneous matters are dissolved, and it presents a clean bright surface.

Platinum is rarely applied to the purposes of the jeweller, silver being preferred; indeed, its chief use, except in Russia, where it is coined, is for chemical apparatus and philosophical instrument making, in the construction of electrical batteries, dentistry, &c. &c. It is chiefly absorbed in the construction of stills for sulphuric acid rectifiers, pans, stills, and digesters employed in the manufacture of drugs and many of the purer chemical preparations. Like silver and gold, this metal, when it is put to use in the various forms in which it is manufactured, is carefully collected and returned to the platinum founders, to be again worked up into the same or other articles. It is usual to allow half price for returned platinum; but this standard is evidently too low when compared with the price of the manufactured goods. The amount of platinum manufactured and traded with annually averages from five thousand eight hundred to six thousand three hundred pounds troy, of which North and South America yield about seven hundred to eight hundred and fifty pounds, and Russia five thousand one hundred to five thousand four hundred and fifty. What is obtained from other sources is small, and does not enter into the foregoing statistics.

ALLOYS.—Platinum forms alloys with several metals, the most interesting to the artisan being those which it yields with zinc, iron, lead, copper, and silver *with zinc*. When one and a half to two parts of zinc are mixed with one part of spongy platinum and heated, vivid combustion of the mass is observed to take place, even before it has attained a red heat. The compound mass has a bluish-white appearance, acquires considerable hardness, and is easily melted, the zinc becoming an oxide if air be admitted. With a quarter of its weight of zinc, platinum is rendered brittle; and zinc, with about a twentieth of its weight of platinum with iron. A powerful heat is required to effect the combination of iron and platinum, which, however, constitute a very hard alloy, scarcely acted upon by the file, and somewhat malleable. FARADAY and STODART have made several experiments upon the alloys formed from steel and platinum. Those averaging from four to nine parts of steel to one of platinum, are characterized by their close texture, which enables them to take a high polish, and by their not tarnishing in the air. An alloy of sixty-seven parts of steel and one of platinum, they found to be well adapted for the manufacture of cutting or edged tools. One part of platinum and a hundred of steel is a metal less hard than silver steel, but tougher. With one of platinum and two hundred of steel, a metal was formed which BRÉANT recommends for the manufacture of razors.

With Lead.—Alloys of lead and platinum have few peculiar or striking characteristics, except that they melt readily, possess a color approaching to purple, and break or split under the hammer.

With Copper.—A sustained white heat is required to induce combination of copper and platinum. In equal quantities they melt, and form a golden-colored alloy very malleable; with one-sixth to one-twenty-fifth of platinum, the color of the alloy is between pale red and rose red; the metal works well under the hammer, and takes a good polish, but it is a little duller in its aspect than pure copper. An alloy of copper and platinum has been introduced for mounting telescopic and other lenses. COOPER prepared an alloy of seven parts of platinum, sixteen of copper, and one of zinc, which is similar to sixteen carat-gold, is very extensible, and remains unaffected by strong nitric and sulphuric acids.

With Silver.—Silver, when combined with platinum, becomes darker in color, less malleable and harder than it is *per se*, and in proportion as the admixture of platinum is increased, its melting point becomes higher. Equal weights of silver and platinum give a hard dull-hued alloy, very brittle under the hammer; when the proportion of silver is more than five per cent. and cupelled with lead, no brightening occurs. Sulphuric acid dissolves part of the silver from the alloys rich in this metal, but nitric acid does not effect the analysis of both metals, as the solution contains both silver and platinum.

With Gold.—Platinum unites with gold, but when the proportions are equal it requires the strongest heat of a wind-furnace to effect the fusion; and when the combination of the two metals in the ratio of three of gold to seven parts of platinum is essayed, the tem-

perature of the oxyhydrogen blast is necessary. The alloys in every instance are characterized by having a lighter color than gold, a great density, and when the gold averages a sixth to a fifth of the weight, considerable elasticity.

COMBINATIONS OF PLATINUM.—This metal is capable of uniting with most of the non-metallic elements; with several of them it readily combines, whilst with others the conditions requisite to effect the combination are varied. In a practical point of view, however, these are uninteresting, as no particular application of them has been made, with, perhaps, the exception of the bichloride, which is in continued request in the laboratory, and in some cases in the potter's art, for producing bright steel greys. Some of the compounds thus produced, more especially the chloride, enter into the formation of other well-marked bodies of a compound saline nature, wherein the platinum compound remains intact, and occupying as it were the part of a radical in the new salt.

It would be useless to describe these combinations here, the more so as they serve but little the purposes of the manufacturer. The bichloride of platinum, which is the most useful of the class referred to, may be prepared as stated when speaking of the preparation of platinum, namely, by treating the metal with aqua regia containing an excess of hydrochloric acid, and evaporating till all the free acid is removed. The salt has a dark red crystalline appearance, is deliquescent, and gives with water and alcohol—in which menstrua it is soluble in all proportions—dark red solutions. Its symbol is Pt Cl_2 , and its atomic or equivalent weight one hundred and seventy.

POTASSIUM.—*Potassium*, French; *Kalium*, German and Latin.—The discovery of this interesting metal was made as lately as the commencement of the present century. The compound nature of the alkaline base—potassa—had long been suspected, though never previously proved to a certainty. Nor were philosophers agreed as to its supposed constitution; for while LAVOISIER suspected it to be a true metallic oxide, the more generally received opinion was, that nitrogen was an ingredient in its composition. The proof of its compound nature, until then merely hypothetical, was reserved for that distinguished philosopher, Sir HUMPHREY DAVY, who in 1807 succeeded by means of a powerful voltaic battery in separating potassium, with the metals of the other alkalies and of the alkaline earths, from their combinations. This, unlike the great majority of discoveries at that period, was not the result of accident, but of true scientific reasoning, and was confidently expected to follow the application of that agent, the extraordinary powers of which had been until this period so little understood and investigated, but which has since been so beneficially applied to the wants of mankind. Lord BROUGHAM, referring to the discovery of this and the other alkaline metals, remarks, that he could well remember that in discussing the subject, they used to look forward with perfect confidence to the analysis of those bodies which had hitherto proved the most stubborn, and expected soon to find the fixed alkalies, and even the alkaline earths, shown to be oxides, as by some very imperfect experiments they

had at one time been supposed to be proved. The discovery was not long delayed. In October, 1807, DAVY, after in vain endeavoring to decompose the alkalies when mixed with water—for then he could only decompose that fluid—exposed them in the dry state, but made liquid by fusion; and to his great delight he found, as he had expected, that the process of decomposition proceeded, the oxygen appearing at the positive wire, while globules of a metallic substance were found at the negative one. The glory of having made the greatest discovery of the age was plainly DAVY'S. His praise would have been the same if, instead of at once discovering the alkalies to be oxides, and the metals forming the bases to be lighter than water, while one of them burned unheated in the open air, he had only shown these salts to be oxides of well-known metals; but as his investigation had been crowned with the discovery of strange substances—metallic, and yet like no other metals—the admiration excited was still greater.

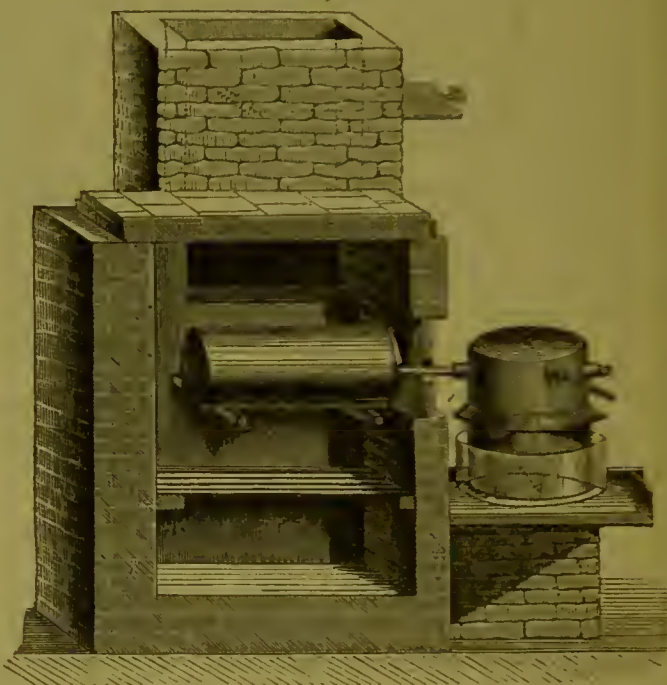
The investigation of DAVY was afterwards prosecuted by GAY-LUSSAC and THÉNARD, who, however, for some time still regarded the metal to be a compound of the alkali with hydrogen. BERZELIUS, on the contrary, repeating DAVY'S experiments, satisfied himself of the correctness of the theory of the latter chemist.

SOURCES.—In consequence of its intense affinity for oxygen, potassium is never met with in nature uncombined. It occurs principally as carbonate of the oxide or potassa in the ashes of land plants, and also as chloride in those of marine plants. In the mineral kingdom, it is found as sulphate, as well *per se*, as in combination with earths and water, and especially in alum and alum-stone. In polyhallite it is associated with the sulphates of lime and magnesia. As nitrate of potassa, or salt-petre, it is found in large quantities on the surface of the earth; as chloride, it exists sparingly in rock-salt, in sea-water, and in many salt springs, and other mineral waters. It is also an ingredient in several rocks, especially in felspar, leucite, apophyllite, and potassa tourmalin, in all of which it exists as silicate of potassa. Being always contained in plants, its salts are of course a most important ingredient in soils.

PREPARATION.—The expensive and troublesome method of DAVY, for the production of this metal, has long been abandoned, or at least is exhibited only as an interesting example of the power of electricity in producing chemical decomposition. The following process invented by GAY-LUSSAC and THÉNARD, and subsequently modified by BRUNNER, WÖHLER, and MITSCHERLICH, is that most frequently adopted. The salt made use of is the carbonate of potassa, and by careful manipulation, large quantities of metal may be obtained. The reducing agent employed is charcoal in a state of the most minute division. These ingredients are most readily procured in a proper admixture by the calcination of *argol*, or crude bitartrate of potassa. MITSCHERLICH directs six pounds of tartar to be ignited in a covered iron pot, till gases cease to be evolved. The product, termed *black flux*, is, while still hot, to be pulverized and mixed with ten ounces of coarsely-powdered charcoal. This addition is intended, by making the mass more porous, to allow of the more

easy escape of the gases subsequently developed. The whole is then transferred as quickly as possible to a wrought-iron quicksilver bottle, to the mouth of which an iron tube, not exceeding five inches in length, is screwed, to serve as a connection to a copper receiver, partly filled with rectified naphtha, and so constructed with partitions as to exclude the air. Another tube is inserted in this receiver, directly opposite to the tube in the bottle, so as, if necessary, by means of a strong steel rod, to cleanse the connecting tube, which occasionally becomes clogged by the products of decomposition. This tube serves also as an escape aperture for the gases. The whole arrangement is fixed in a wind furnace, as shown in Fig 421. This furnace should have a wide grate,

Fig. 421.



and a chimney ten feet high. The receiver is kept cool by means of ice applied to the outside. A strong and uniform heat, produced by the combustion of dry wood, is then applied to the bottle, and when the mass is sufficiently heated, the decomposition of the alkali by the charcoal begins, indicated by the appearance of a pink flame at the mouth of the tube. The potassium now distils over, accompanied by carbonic oxide and some solid products, and, dropping into the naphtha in the receiver, is effectually protected from the action of the air.

Instead of the iron bottle used in the above process, a gun barrel is sometimes employed, and is bent upwards at the thick end at a very obtuse angle, and downwards at the other end for about four inches, the middle part being laid horizontally in the furnace. This is the form of apparatus originally employed by GAY-LUSSAC and THÉNARD. The ingredients used by these chemists were hydrate of potassa, and metallic iron in the form of wire, filings, or borings. The latter were placed in the middle of the tube, and the potassa salt contained in the anterior bent portion of the tube was gradually fused and allowed to flow down; and coming in contact with the iron at a white heat was decomposed, yielding potassium and hydrogen

gas, which latter escaped by the lower end of the barrel, and the potassium was collected as previously described. To preserve the iron bottle or gun barrel used in these processes from wasting away rapidly by the action of the intense heat, it has been recommended to coat them externally with luting. GAY-LUSSAC and THÉNARD used for this purpose a mixture of one part of clay, five of fine sand, and a small quantity of horse dung; this luting is slowly dried, and the cracks filled up with fresh material. MANTELL incloses the gun barrel in a tube of baked clay, of such a width as to allow of the expansion of the barrel. SCHADLER and WERNER surround the bottle with a wire net, and on this the former applies a luting composed of two parts of pounded Hessian crucibles, one part of pipe-clay, and some cow hair; the latter two or three coatings of thin paste consisting of coarse quartz sand and a little clay. ANTHON covers the bottle with a mixture of loam and sand, and GALE with a mixture of equal parts of sand, clay, and soap-stone.

Instead of the mixture of charred tartar and charcoal, recommended by MITSCHERLICH, one of carbonate of potassa and charcoal in proper proportions may be used. KUKLA evaporates to dryness a mixture of three parts of pearlash dissolved in water, with the addition of one part of flour, carbonizes the residue, mixes it when cold with sufficient water to moisten it slightly, and transfers it to the bottle. It is always desirable to employ an excess of charcoal, as the rapid choking of the tube, as well as the fusion and projection of the contents of the bottle, is thus prevented. If a complete stoppage is actually formed in the tube, the greatest care must be exercised in reopening it; and if the attempt be successful, which is not always the case, masses of burning potassium may be forcibly projected by the sudden expansion of the compressed gas in the bottle, and occasion serious injury to the operator. The latter should therefore expose himself as little as possible, and his hands should be carefully protected by leathern gloves. The metal adhering to the borer should also be quickly scraped off into naphtha or rock oil, and should it take fire, extinguished by covering with a plate.

The theory of the production of potassium from the carbonate of potassa, by heating in contact with charcoal, is not clearly understood. In its simplest form, the decomposition may be represented thus— $\text{K}_2\text{O} + \text{CO}_2 = 2\text{K} + 3\text{CO}$. Unfortunately, however, the greatest portion of the potassium at the moment of separation enters into combination with the carbonic oxide, forming a grey powder termed croconaceous matter, and from which, by digestion in water, *croconate* and *rhodizonate* of potassa may be separated. The grey powder is possessed of most powerfully explosive properties, and if the greatest care be not exercised in removing it from the tube and other parts of the apparatus—such as carefully excluding it from the atmosphere until quite cool, and soaking well in naphtha previous to attempting its removal—the most dangerous accidents may occur. The loss in potassium, owing to the formation of these compounds, is very great—amounting even under the most favourable circumstances to at least one half of the metal contained

in the mixture. PLEICHL obtained from six pounds of tartar, carbonized and mixed with six ounces of charcoal, nine and a quarter ounces of potassium, equal to 9.2 per cent. This is nearly one half of the total amount present, and may be considered a good yield. In most cases the product is much less.

PURIFICATION.—Potassium, as obtained in the processes above described, is found in the receiver in the form of globules mixed with carbonaceous matter. From this the visible globules are picked out with a pair of forceps, and by distilling the black residue a further quantity may be separated. The metal thus collected is, to separate remaining impurities, tied up in a linen bag and heated to about 150° , and then pressed out with a pair of wooden tongs. A far more effectual method of purification is, however, by distillation from a small iron retort, with which a short wide tube is connected, as represented in Fig.

Fig. 422.



422. This bottle is, after being filled with the crude metal, slowly raised to a strong red heat in a small air furnace. The potassium after some time begins to pass over, and is received into naphtha. The process requires to be conducted with great caution, otherwise a dangerous explosion may ensue. Under any circumstances there is a considerable loss of metal from oxidation and other causes.

PROPERTIES.—Potassium is of a bluish, or silver-white color, and is possessed of a high degree of metallic lustre. Its consistence is very variable according to the temperature; below 32° it is brittle, and its fracture has a crystalline texture. At 60° it is malleable, and easily cut with a knife. At about 130° it enters into perfect fusion, and in appearance resembles mercury; and at a bright red heat it boils and rises in green vapor. Its specific gravity at 60° is 0.865; it is, therefore, lighter than water. When exposed to the air, potassium is instantly tarnished by the formation of a film of oxide; indeed so powerful is its affinity for oxygen, that when thrown on the surface of water, it instantly takes fire, forming potassa and liberating hydrogen gas. Potassium must always, therefore, be kept in naphtha, rock oil, or some liquid free from oxygen. The brilliant lustre of this metal is most beautifully shown by heating it in melted tallow, or by pressing a small portion between two plates of glass. The symbol for potassium is K, and its equivalent 39. Owing to its intense affinity for oxygen and the other metalloids, potassium is a most powerful instrument of research; thus, it decomposes all oxides, in most cases with complete reduction; and, with the aid of heat, all carbonates, phosphates, sulphites, sulphates, nitrates, and many other salts, withdrawing the oxygen not only from the acid, but also from the base. By its means many metals, previously unknown in the separate state, have been withdrawn from their combinations, and may now be prepared in any quantities to supply the demand for them in the arts and manufactures. Potassium has also been employed in surgery, as a substitute for the

actual cautery; in some cases with most beneficial results.

OXIDES OF POTASSIUM.—By combining with oxygen, this metal forms three compounds—suboxide, K_2O ; protoxide, KO ; and peroxide, KO_2 . The first named is produced when potassium is heated with a limited supply of air in a close vessel, or when it is heated with the higher oxides. The protoxide is obtained when an equivalent of potassium is allowed to act upon one of water, in a vessel from which the air is carefully excluded.

The decomposition is as follows:—



It is also procured by exposing the peroxide to a strong heat. The latter—the highest oxide—is produced when the metal is burned with free access of air or oxygen gas, by burning the suboxide and the protoxide, and also by the continued ignition of the nitrate of potassa. None of these oxides, *per se*, are of use in the arts or manufactures, and therefore will not require further mention. The protoxide, however, in combination with water, is a most important salt, and demands a more detailed notice.

HYDRATE OF POTASSA—Caustic Potassa.—This salt is most conveniently prepared by decomposing carbonate of potassa by hydrate of lime. One part of the carbonate is heated with twelve parts of water till the solution boils; slaked lime—prepared by mixing three parts of warm water with a little less than one of burned lime, and keeping it in a covered pan till the latter is reduced to a soft powder—is gradually added with constant agitation. The vessel is then covered, and its contents boiled for a quarter of an hour. The caustic solution is now tested by decanting a small portion and pouring it into hydrochloric acid; if there be no effervescence, the potassa is completely decomposed; in the contrary case, longer boiling, perhaps with the addition of more lime, is requisite. When a portion of the liquid no longer disengages carbonic acid on the addition of a stronger one, the whole is allowed to remain at rest for some time, in order that the carbonate and the excess of hydrate of lime may subside. The clear liquor is then siphoned off, concentrated by evaporation in covered iron pots, and, should it become turbid, set aside for some time and then again decanted. Lastly, the solution is rapidly boiled down in a polished iron or silver vessel till it acquires the consistence of oil, and on cooling concretes into hard masses. Carbonate of potassa is also decomposed by lime at ordinary temperatures; but in this case the decomposition is effected less rapidly, and the carbonate of lime formed being much less dense than when ebullition is used, its separation is much more difficult. As thus prepared, this hydrate frequently contains considerable quantities of alumina, silica, and phosphoric acid.

For use in the laboratory, hydrate of potassa, prepared as above, is treated with rectified spirit of wine in a stoppered bottle. The solution is allowed to deposit, decanted and evaporated in a silver dish, until fumes cease to be evolved, adding from time to time during the evaporation some water to prevent blacken-

ing of the mass. Except a minute trace of alumina, this hydrate, if carefully manufactured, is free from other impurities.

To obtain it perfectly free from alumina, SCHUBERT directs hydrate of potassa to be prepared by decomposing the sulphate of that base by means of hydrate of baryta. A solution of this latter salt is added to one of pure sulphate of potassa in exactly sufficient quantity to effect decomposition. The decanted solution is then evaporated as previously described.

A still better method for the production of this salt in a state of chemical purity is the following, recommended by WÖHLER. Put one part of nitrate of potassa, and two or three parts of sheet copper cuttings, in an iron or copper crucible in alternate layers; cover the latter, and expose it for half an hour to a moderate red heat. Allow the mass to cool, treat it with water, let the solution deposit in a tall cylinder, and afterwards remove it by means of a siphon. By evaporation the perfectly pure hydrate may then be obtained.

According to FUCHS, hydrate of potassa may be economically obtained from certain varieties of felspar and from mica. For this purpose the minerals are calcined with lime, then left for some time in contact with water, and the solution is afterwards filtered and evaporated. From his statement it appears that nineteen per cent. of potassa may be obtained from felspar, and fifteen per cent. from mica.

Hydrate of potassa is a white opaque mass, which, when broken, exhibits a crystalline fracture. Its specific gravity is 1.7. It fuses at a low-red heat, and at a white heat volatilizes unaltered. Its taste is acrid and corrosive. It has a strongly alkaline reaction, a rapid solvent action on animal matters, and is the most powerful base known. Its formula is KO, HO ; it is very deliquescent, very soluble in water, and crystallizable. The following table, deduced from DALTON'S experiments, shows the quantity of anhydrous potassa contained in solutions of various densities:—

Specific gravity.	Potassa per cent.	Boiling point. Degrees
1.68	51.2	329
1.60	46.7	290
1.52	42.9	276
1.47	39.6	265
1.44	36.8	255
1.42	34.4	246
1.39	32.4	240
1.36	29.4	234
1.33	26.3	229
1.28	23.4	224
1.23	19.5	220
1.19	16.2	218
1.15	13.0	215
1.11	9.5	214
1.06	4.7	213

The latter is about the strength of the solution of potassa of the London Pharmacopœia.

The impurities most frequently met with in solution of and solid hydrate of potassa are carbonate of lime, oxide of iron, silica, alumina, carbonate and sulphate of potassa, and chloride of potassium. Carbonic acid is indicated by effervescence on the addition of an acid. Carbonate of lime and oxide of iron remain insoluble when the salt is treated with water. Silicic acid and

alumina are precipitated when an acid is gradually added to saturation, and the latter is redissolved by a slight excess of acid. The presence of a sulphate is shown by the addition of nitrate of baryta to a solution previously acidulated with nitric acid, and of chloride of potassium, by adding nitrate of silver to a portion of the same solution.

Hydrate of potassa is a most valuable agent to the chemist, and especially in the estimation of the carbon of organic bodies. It is also used to displace metallic oxides from their combinations, as a solvent for oxides of zinc and alumina, also for the decomposition of silicious minerals by fusion, for drying certain gases, and a variety of other purposes. In surgery, it is used in the solid state, cast into sticks, as a most powerful caustic. In medicine, its solution is also frequently employed, especially as an antacid.

Physiological Effects.—In the solid state its local action is remarkably energetic, rapidly destroying the tissue with which it comes in contact. When dissolved it is also powerfully corrosive, and consequently an energetic poison in large doses. It excites no constitutional action, except what depends on the local injury it occasions. In medicinal doses it possesses antacid and antilithic properties, and is administered in some bitter infusion.

CARBONATE OF POTASSA—*Potashes, Pearlash, Salt of Tartar.*—This salt is most readily obtained in a state of purity by heating the crystallized bicarbonate to a temperature exactly sufficient to expel its water and half of its carbonic acid, which is effected below a red heat. The residue dissolved in water and filtered yields the pure salt by evaporation. The solution in water and filtration is for the purpose of separating a small quantity of silica usually contained in the bicarbonate, and which is rendered insoluble by heating. If, however, the salt is heated too strongly, a silicate of potassa is formed, which dissolves with the carbonate; while, on the other hand, if not sufficiently heated, the residue still contains soluble silica. The pure salt may also be obtained by heating the bitartrate of potassa, or a mixture of nitrate and bitartrate to redness, lixiviating the residue, and evaporating to dryness; also, by passing carbonic acid into solution of potassa till saturated, evaporating to dryness, and exposing the mass to a dull red heat.

Properties.—Carbonate of potassa— KO, CO_2 —is very soluble in water, and the solution, when concentrated to about 1·2 and suffered to cool, deposits crystals containing two equivalents of water, and therefore having the formula $\text{KO}, \text{CO}_2, 2 \text{HO}$. As usually met with, it forms a white solid anhydrous mass, deliquescent, and at a red heat fusible without alteration. Its solution has a powerfully alkaline reaction and taste, but is only slightly caustic. It rapidly abstracts water from the atmosphere, and yields a dense solution originally termed *oil of tartar per deliquium*. The specific gravity of the pure anhydrous salt is 2·24. It is insoluble in absolute alcohol. Boiling water, on the contrary, dissolves more than its own weight of this salt. A cold saturated solution contains about forty-eight per cent., and its density is about 1·5. The subjoined table by TUNNERMANN shows the quantity of anhy-

drous salt contained in solutions of the densities enumerated:—

Specific gravity.	Per cent.	Specific gravity.	Per cent.
1·4812	40·504	1·2282	19·580
1·4750	40·139	1·2150	18·601
1·4626	39·160	1·2020	17·622
1·4504	38·181	1·1892	16·643
1·4384	37·202	1·1766	15·664
1·4265	36·223	1·1642	14·685
1·4147	35·244	1·1520	13·706
1·4030	34·265	1·1400	12·727
1·3915	33·286	1·1282	11·748
1·3803	32·307	1·1166	10·769
1·3692	31·328	1·1052	9·790
1·3585	30·349	1·0940	8·811
1·3480	29·360	1·0829	7·832
1·3378	28·391	1·0719	6·853
1·3277	27·412	1·0611	5·874
1·3177	26·432	1·0505	4·895
1·3078	25·454	1·0401	3·916
1·2980	24·475	1·0299	2·934
1·2836	23·496	1·0108	1·958
1·2694	22·517	1·0098	0·979
1·2554	21·538	1·0048	0·489
1·2417	20·539		

The carbonate of potassa of commerce—usually termed *potashes* or *pearlash*—is an article of great importance in the arts and manufactures; and it is, therefore, necessary to dwell at some length on its production, the methods for procuring it on the large scale, and its purification for manufacturing purposes. As previously mentioned, potassa is an essential ingredient in plants, and it is from this source that the carbonate is obtained for commercial purposes; for though some other salts of this base are frequently met with in nature and in large quantities, still potashes are never procured on the large scale by a chemical decomposition of these salts. The great natural depository of potassa is the felspar of granite and other unstratified rocks, where it exists in combination with silica, and quite insoluble in water. Its extraction directly from this source, though it has been attempted on the large scale, is attended by difficulties so great as probably never to allow its successful prosecution. As the rocks disintegrate into soils, however, the alkali acquires solubility; and, being taken up by plants, it accumulates in their substance in a condition highly favorable to its subsequent applications. The precise condition in which potassa is contained in the vegetal kingdom, is to a great extent involved in mystery; and the same may be said, also, as to the part it plays in the organism of plants. A considerable portion, however, undoubtedly exists in combination with vegetable acids—as tartaric, citric, malic, and oxalic—and in smaller quantities in some plants as carbonate. Besides potassa, however, all vegetals contain other inorganic constituents in variable proportion—as, for instance, chlorides of potassium and sodium, sulphates of potassa and soda, carbonates and phosphates of lime and magnesia, silicate of alumina, some metallic oxides, as those of manganese, iron, and copper, and also nitric acid, iodine, and bromine, in combination with oxides and metals. The alkalies, potassa and soda, appear to be capable of replacing each other in the constitution of plants, as it is found that in those growing on the shores of the ocean, where the latter base is of course more abundant, it usually predominates; while in plants produced on an inland soil, potassa is always prepon-

derant; indeed, according to CHAPTAL and FONTENELLE, the same plants which, when cultivated at a short distance from the sea, yield soda salts, when reared at a distance of ten leagues produce salts of potassa. Other researches which have been made upon this subject leave no doubt that plants, in the absence of a particular ingredient in a soil, can take up some other, which, as regards chemical action, is endowed with similar properties, and that bases replace each other and act conjointly with reference to the functions of plants. This property of plants to secrete other principles than those generally supposed to be essential to their growth, and which appear to be their natural sustenance, is very remarkable; it is, nevertheless, of frequent occurrence—indeed, the ashes of two specimens of the same species of plants are seldom perfectly alike in composition, and are often considerably at variance. Thus, SAUSSURE found in the ash of a fir the following ingredients:—

	Per centage
Carbonate of potassa,	3.6
“ lime,	46.34
“ magnesia,	6.77

In the ash of the same tree, but grown in another locality, he found of—

	Per centage.
Carbonate of potassa,	7.36
“ lime,	51.19
“ magnesia,	0.00

In both cases the proportion of oxygen in the base of the salts is precisely the same—namely, 9.0. It appears, therefore, that the action of a base is dependent upon the amount of oxygen it contains, and is, indeed, measured by that quantity; the bases of such ashes—independent of that portion which is in combination with mineral acids—must together contain one and the same quantity of oxygen. This view is confirmed by the experiments of WILL and FRESENIUS, who obtained from the ashes of tobacco very variable results as to the proportion of the different ingredients; but as regards the oxygen of the base, the total amount in one case was 24.27, and in the other 24.57. The nature of the ash also, as proved by SAUSSURE, varies in the same specimen with the part of the plant from which it is obtained, and, even in the same part is not uniform throughout the different periods of development and changes of season.

The first operation in the production of potassa is the combustion of the wood, when, after the volatilization of the destructible matters—as carbon, hydrogen, *et cetera*—all the mineral constituents abstracted from the soil naturally remain in a fixed state. This residue may contain all, or only a portion of, the constituents previously mentioned as the mineral food of plants. The bases—potassa and soda—are found for the most part as carbonates, formed during incineration from the decomposition of the vegetal acids with which they were combined. In general, the herbaceous plants yield much more ash than shrubs, and these again more than trees. In the latter the bark and leaves afford the largest quantity, next the branches and twigs, while in the trunk only a very small quantity is contained. The subjoined table shows the centesimal

amount of ash obtained from the plants mentioned, together with the name of the authority:—

Trees.	Part burnt.	Per centage.	Authority.
Oak,	wood,	2.30	.. Berthier.
“	branches,	0.40	.. Saussure.
“	bark,	6.00	.. Berthier and Saussure.
“	leaves,	5.5	.. Saussure.
Red beech,	wood,	0.612	.. Mollerat.
“	bark,	6.62	.. Hertwig.
Hornbeam,	wood,	0.60	.. Saussure.
“	sap wood,	0.7	.. “
“	bark,	13.4	.. “
Alder,	wood,	0.40	.. Karsten.
Birch,	wood,	0.30	.. “
Pinus picea,	wood,	1.50	.. “
“	seeds,	4.47	.. Will and Fresenius.
“ abies,	wood,	0.25	.. Karsten.
“	bark,	1.78	.. Hertwig.
“	needles,	2.31	.. “
“ sylvatica,	wood,	1.19	.. Saussure.
“	needles,	2.60	.. “
“	seeds,	4.98	.. Will and Fresenius.
Lime,	wood,	5.00	.. Berthier.
Poplar,	wood,	0.80	.. Saussure.
Elm,	wood,	2.28	.. Mollerat.
Ash,	wood,	2.30	.. “
Shrubs.			
Elder, .....	..	1.64	.. Berthier.
Hazel, .....	..	0.50	.. Saussure.
Wortleberry, .....	..	2.60	.. “
“ .....	..	0.68	.. Mollerat.
Blueberry, .....	..	0.71	.. “
Juniper, .....	..	1.84	.. “
Wild rose, .....	..	0.71	.. “
Heath, .....	..	1.41	.. “
Green weed, .....	..	1.62	.. “
Heckle, .....	..	1.66	.. “
Blackberry, .....	..	0.76	.. “
Broom, .....	..	1.48	.. “
Sumach, .....	..	1.71	.. “
Herbs.			
Potato straw, .....	..	15.00	.. Berthier.
“ leaves, .....	..	1.15	.. Mollerat.
Peas haulm, .....	..	5.05	.. Hertwig.
“ .....	..	11.30	.. Boussingault.
“ .....	..	8.10	.. Saussure.
Oat straw, .....	..	5.10	.. Boussingault.
Nettle, .....	..	10.67	.. Pertuis.
Thistle, .....	..	4.03	.. “
Rushes, .....	..	4.33	.. “
Wheat straw, .....	..	4.40	.. Berthier.
“ .....	..	7.00	.. Boussingault.
“ .....	..	4.30	.. Saussure.
Rye straw, .....	..	0.30	.. Karsten.
“ .....	..	3.60	.. Boussingault.
Maize straw, .....	..	12.20	.. Saussure.
Cane straw, .....	..	1.70	.. Karsten.
Fern, .....	..	2.75	.. “
“ .....	..	2.90	.. Mollerat.
“ .....	..	5.00	.. Pertuis.
Plantain leaves, .....	..	9.22	.. Abbene.
“ branches, .....	..	2.30	.. “
Acacia, .....	..	2.46	.. “
Vine, .....	..	4.66	.. “
Grape stalk, .....	..	8.89	.. “
Vine pith, .....	..	7.29	.. Blengirie.

The proportion of carbonate of potassa contained in the ashes of wood is also very variable, and it is always associated with a greater or less quantity of carbonate of soda. Other soluble salts are sulphates and silicates of these alkalies, and chlorides of the metals. If the ash is treated with water, these salts are separated, whilst carbonates, phosphates, and silicates of the alkaline earths remain insoluble. The value of a particular ash is, therefore, determined by the estimation of the relative proportion of its soluble and insoluble

constituents. In the appended table are given the experiences of BERTHIER and others on this point:—

Ashes.	Soluble.	Insoluble.	Authority.
White beech wood,	19.22	80.78	Berthier.
White beech charcoal,	18.00	82.08	"
Red beech wood,	16.30	83.70	"
Oak wood,	12.00	88.00	"
Oak charcoal,	15.50	84.50	"
Oak bark,	6.25	93.75	"
Lime wood,	10.80	89.20	"
Birch wood,	16.00	84.00	"
Alder wood,	18.80	81.20	"
Fir wood,	25.70	74.30	"
Fir charcoal,	50.00	50.00	"
Pine wood,	13.60	86.40	"
Pine needles,	12.70	86.30	Hertwig.
Mulberry tree,	25.00	75.00	Berthier.
Nut-tree wood,	15.40	84.60	"
Elder wood,	31.50	68.50	"
Wheat straw,	10.10	89.90	"
Potato straw,	4.20	95.8	"
Fern,	29.00	71.10	"
Bean straw,	32.91	65.97	Hertwig.
Pea straw,	27.82	72.18	"
Rye straw,	19.47	80.26	Fresenius.

Extraction of Potashes.—The American process for the extraction of potashes is thus described by MORFIT. The incineration of the plant is effected in dry pits, sunk into the ground to a depth of three or four feet. The plant is thrown in in portions, and burned until the pit is nearly full of ashes. The latter are then removed, mixed with about five per cent. of lime, and drenched with successive portions of fresh water. The ash-tubs or vats employed in this operation are usually formed from tar-barrels, by cutting them in half. A number of these are furnished with two cross-beams, upon which rests a false cullendered bottom covered with straw, and below this is a cock for the removal of the lie. The first liquor running through being saturated is passed at once to the evaporating pan; while the second or third runnings, being weaker, are reserved and poured upon fresh ash until completely saturated. The evaporating pans are broad and shallow, and made of iron with corrugated bottoms, to produce greater extent of heating surface; and as evaporation progresses, new supplies of strong liquor are poured in, and the heat is continued until a sirupy consistence is attained, when the fire is gradually slackened, and the contents of the pan, becoming solid, are dug out and placed aside as *crude potashes*. By subjecting this mass to the heat of a reverberatory furnace, most of the sulphur, and all excessive water and empyreumatic matters are expelled, causing a loss of ten to fifteen per cent. This modified product is white, with a bluish tinge, contains more carbonic acid than the original crude product, and takes the name of *pearlash*.

The process employed in Russia and Northern Europe is the same in principle as that above described, and is conducted in a similar manner, except that no lime is used in the lixiviation process. The difficulty experienced in the removal of the potashes from the evaporating pans may be avoided, in a great measure, by constant agitation of the lie while cooling. The salt thus obtained, however, contains twice as much water as in the ordinary method. By some producers a separation of the greater part of the difficultly soluble

sulphate of potassa—a salt largely consumed by the manufacturers of alum—is effected by evaporation and cooling from the lie, which has been saturated with the soluble constituents of the ash, and a much superior variety of potash is obtained.

The insoluble portion of the ashes of plants, and which remains in the lixiviating vat, is employed in glasshouses for the production of green bottle-glass, and, on account of the phosphates it contains, is also valuable as a manure.

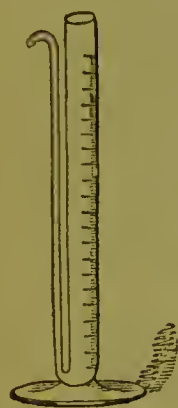
The production of potashes is principally carried on in those countries where, being thinly populated, wood is very abundant. In Russia, straw and weeds are burnt for the potassa they contain; and in some districts of France, yeast, the lees of wine, and distillery refuse are also applied to the same purpose; while in Java, potashes are extracted from the stems and leaves of the indigo plant, after the separation of the coloring matter.

The principal varieties of potashes met with in commerce are American, Russian, German, Saxon, and Dantzic. They vary but little in appearance, and derive their names from the locality whence they are imported. The proportion of carbonate of potassa contained in the crude ashes varies from forty to eighty per cent., and the residue for the most part consists of sulphate and silicate of potassa and chloride of potassium. According to the analysis of VAUQUELIN, American potashes contain of pure hydrated potassa—either in the free state, or combined with carbonic acid—74 per cent., Russian potashes 67, and American pearlashes 65.5 per cent. Various European specimens, also examined by this chemist, yielded from 38.5 to 62 per cent.

Valuation of Potashes—Alkalimetry.—The commercial value of potashes depends entirely upon the proportional amount of carbonate or caustic alkali contained in them; and it is, therefore, important to be able to effect the estimation of these salts otherwise than by a complete chemical analysis, as the tediousness of the operation, the great practice required in manipulation, and the cost of apparatus, render any such method nearly impracticable to the manufacturer. Several processes have been devised to ascertain the amount of available alkali in the crude product with sufficient accuracy for the purposes of commerce. Amongst these, the one most frequently adopted is that first broached by RICHTER, afterwards practised by DESCROIZELLES, and subsequently improved by GAY-LUSSAC. It consists in determining the quantity of an acid required to neutralize the alkaline reaction of a known weight of the salt to be examined, which, of course, represents the amount of available alkali present. Sulphuric acid is generally employed for this purpose; for while it wholly expels the carbonic acid, and combines with the whole of the free alkali, it does not extend its decomposing influence to the foreign salts in any important degree. The measure used in this process, termed an *alkalimeter*, is shown in Fig. 422. The cylinder is usually about twelve inches in height, and three-fifths of an inch internal diameter, and is graduated uniformly downwards into one hundred divisions.

For estimating the value of potashes, the following is the most convenient method. A quantity of sulphuric acid is taken and gradually added to about nine times its bulk of water, and the mixture is allowed to cool; 112.75 grains of perfectly pure anhydrous carbonate of soda are then taken and dissolved in about a half-pint of water, and the solution is heated. The

Fig. 422.



alkalimeter is now filled to exactly one hundred measures with the mixture of acid and water, and the latter is gradually poured into the soda solution to complete saturation. The number of measures of acid used is then carefully read off, and these are exactly equivalent to one hundred grains of pure potassa. If, therefore, eighty measures of acid are required, by adding to every eighty measures remaining twenty additional measures of water, an acid is obtained of which one hundred alkalimeter measures exactly represent one hundred grains of potassa—that is, one grain to each measure. If a greater or less quantity of acid is required for the saturation of the carbonate of soda, the quantity of water required to be added to the acid is diminished or increased according to such proportion, so that one hundred measures of the acid liquid shall contain exactly the quantity of the stronger acid used to effect the neutralization of the soda salt.

All that is now required, in order to ascertain the quantity of real potassa in any sample of potashes or pearlash, is to dissolve one hundred grains of the sample in warm water, filter, to remove all insoluble matters, and add the dilute acid in small successive portions, until, by the test of litmus paper, the solution is exactly neutralized. Each division of the acid added indicates one grain of pure potassa.

With regard to the performance of the operation, it is necessary to exercise great care to hit the exact point of saturation of the alkali. With caustic alkali this may be effected with ease; but in the case of the salt under discussion, the liberated carbonic acid, which imparts a red tint to the litmus paper, causes some difficulty. The first addition of the acid, however, does not produce effervescence, because the carbonic acid expelled, instead of escaping, combines with the carbonate as yet undecomposed, converting it into bicarbonate; but as soon as half the quantity of potassa contained in the solution is saturated, effervescence ensues, and the solution containing free carbonic acid now changes the blue color of litmus to purple or bluish-red. On the addition of more acid, with constant stirring of the solution, and with increased caution as the point of neutralization is approached, which is known by repeatedly testing with the litmus, until only one drop is added at a time, when the alkali is exactly saturated, the slightest excess of acid produces a permanently red stain after drying. The alkalimeter is then allowed to rest for a short time, in order that the liquid may drain from the sides, and the number of divisions of acid employed is carefully read off, and the per centage amount of potassa contained in the salt examined is at

once ascertained, being equivalent to the number of measures of acid used.

A modification of the above alkalimetric process has lately been proposed by MOHR which gives good results. Instead of sulphuric acid, he employs crystallized oxalic acid. The great disadvantage of this method is, that besides the solution of acid, a standard solution of soda is required as a counter test. In his process the alkali to be examined is dissolved in water, and the solution colored blue with tincture of litmus. As much of the test acid is then added as will suffice to impart a violet color to the fluid. The latter is then boiled, and receives a further addition of acid until the color is decidedly yellowish-red. The alkali is lastly oversaturated with acid, and the last traces of carbonic acid are removed by boiling, *et cetera*. The excess of acid used is now ascertained by addition of the test solution of soda to exact neutralization, and deducting this from the whole quantity employed, the quantity of crystallized oxalic acid required for the saturation of the alkali is ascertained. Every sixty-three grains of this acid represent forty-eight grains of pure potassa.

In the laboratory of the chemist, indeed wherever the examination of alkaline solutions, besides those of potassa, is frequently practised, an acid is prepared that may be adjusted for all alkalies, that is, of such a strength that one thousand grains measure will exactly saturate a certain quantity of each base. The mode of effecting this object is as follows:—An alkalimeter is used of similar construction to that previously described. Into it are poured one thousand grains of water, and the space it occupies is accurately graduated into one hundred equal parts. Opposite to the numbers 23.44, 54.63, 58.96, and 65.0, lines are traced—the first of which is marked *soda*; the second, *carbonate of soda*; the third, *potassa*; and the fourth, *carbonate of potassa*. Dilute sulphuric acid is now prepared, of specific gravity 1.127 at 60°, and is made by adding to one measure of concentrated acid four measures of water. This standard acid is of such strength, that when poured into the tube till it reaches either of the four marks above-mentioned, the exact quantity is obtained for the neutralization of one hundred grains of the alkali, the name of which is written opposite to it. If water be now added until it reaches the beginning of the scale, each measure of the mixture will exactly neutralize one grain of the alkali named, and at once shows the centesimal amount of pure caustic or carbonate of alkali contained in the sample under examination. The strength of the acid is verified by the means previously described, and the process is conducted precisely in the manner directed in the estimation of the potassa salt.

The various kinds of alkali of commerce usually contain a greater or less proportion of chlorides and sulphates. The presence of these does not interfere in the slightest degree with the above methods of estimation. In some cases, however, sulphides, sulphites, and hyposulphites are also present, and these, neutralizing a certain quantity of the test acid, render the determinations more or less inaccurate. The first of these salts evolves sulphide of hydrogen, the second sulphurous acid, and the last hyposulphurous acid, which is immediately decomposed into sulphurous acid

and sulphur. On the addition of an acid, therefore, to a portion of the salt under examination, the presence of sulphite or hyposulphite is indicated by the intensely penetrating nature of the sulphurous vapor eliminated, while a sulphide is shown to be present by the blackening of a slip of paper moistened with acetate of lead and a little ammonia, and placed in contact with the evolved gas. A single experiment serves for the detection of both gases, as it has been lately shown, though previously disputed, that the two may be simultaneously evolved. Should the salts of these acids be proved to be present, the error they would introduce is easily obviated by the addition of a little neutral chromate of potassa, the acid of which immediately transforms the sulphites, hyposulphites, and sulphides into sulphates, with separation of water and sulphur.

An alkalimetric process, varying in principle from those above described, has been devised by FRESSENIUS and WILL, and consists in ascertaining the amount of carbonic acid contained in the sample to be examined, and which is displaced on the addition of an acid. As in the preceding processes, any insoluble matters must be separated by treatment with water and filtration, and if, besides carbonate, caustic alkali is also present, this must be converted into carbonate as follows:—The solution of the weighed portion of the sample after filtration is evaporated nearly to dryness, and solution of carbonate of ammonia is added in excess; the evaporation is then continued, and the residue is finally dried at a high temperature, so as to expel all traces of undecomposed carbonate of ammonia. This salt yielding its carbonic acid to the more powerful base, converts the whole of the latter existing as caustic into carbonate of the alkali. The dry residue is then transferred to an apparatus—Fig. 423—carefully rinsing the dish, and adding the washings to the salt. The rest of the

was made in 1752 by CARTHEUSER. He directs it to be prepared by adding to a solution of the neutral carbonate of potassa as much carbonate of ammonia as will yield to the potassa salt a quantity of carbonic acid equal to that already present. The proportions employed by DUFLOS are four parts of carbonate of potassa, four of water, and one of carbonate of ammonia. The operation is conducted in a retort, that the evolved ammonia may be collected. After boiling for an hour, the solution is left to cool, when a separation of crystals of bicarbonate ensues. These are removed, and to the mother-liquid is added an equal quantity of the ammoniacal salt, and the process is continued as before. Bicarbonate of potassa is also produced when a solution of neutral carbonate is saturated with carbonic acid, and this process is the one usually employed. The carbonic acid gas eliminated during the fermentation of saccharine solutions is frequently applied to the production of this salt, or it may be liberated from marble or chalk by means of dilute sulphuric or hydrochloric acid. Before coming in contact with the potassa solution, the gas is conducted through a bottle half filled with water, to wash away any impurities that may be mechanically carried over. When the solution no longer absorbs carbonic acid it is set aside, to allow the deposition of crystals, of which a further quantity may be obtained by concentration of the mother-liquid, and a further addition of carbonic acid.

Properties.—Bicarbonate of potassa, in the crystalline condition, has the form of an oblique rhombic prism, and is combined with an equivalent of water. Its formula is $\text{KO}, 2 \text{CO}_2, \text{HO}$. It is unalterable in the air, but when strongly heated loses half its acid and the whole of the water, reverting to the state of neutral carbonate. When heated in water, also, it is partially decomposed, and, by long boiling, completely, with production of neutral carbonate. The taste and reaction of bicarbonate of potassa is slightly alkaline. It dissolves in four parts of water at 60° , and in little more than its own weight of this liquid at a boiling heat. In alcohol it is nearly insoluble. It is occasionally employed in the preparation of pure neutral carbonate of potassa.

Physiological Effects.—This salt, as well as the preceding, is possessed of antacid properties. It is, however, much less corrosive than the neutral carbonate. Like this latter salt, it has also diuretic and antilithic properties; and being less unpleasant to the taste, as well as less irritating, it may be administered in much larger doses. It is frequently used also for producing effervescing powders.

SULPHATE OF POTASSA—*Vitriolated Tartar, Salpolycrest.*—This salt is most conveniently prepared by neutralizing with carbonate of potassa the bisulphate of this base, as obtained in the preparation of nitric acid, or by expelling the excess of sulphuric acid by heating the bisulphate to redness. It may also be formed synthetically by saturating carbonate of potassa with diluted sulphuric acid, and evaporating the liquor that crystals may be formed. Sulphate of potassa— KO, SO_3 —is especially distinguished by its hardness. The form of the crystal is that of a six-sided prism. These crystals contain no water of combination; but when heated,

Fig. 423.



operation is conducted precisely as described in the estimation of manganese ore—omitting the oxalate of potassa. Every twenty-two grains loss of weight in the apparatus represents forty-seven of potassa, or thirty-one of soda, according to the salt under examination.

Bicarbonate of Potassa.—The discovery of this salt

decrepitate, owing to the volatilization of a small portion of this liquid mechanically held. Exposed to red heat, sulphate of potassa fuses, but without decomposition, and at a white heat, volatilizes. The taste of this salt is bitter, and feebly saline. It dissolves in about eleven parts of water at 60° , and four at 212° . In alcohol, and in solution of potassa, it is quite insoluble. It is principally employed in the production of alum and saltpetre. Both sulphate and bisulphate of potassa are also used in medicine as gentle laxatives, and the latter salt occasionally to replace the vegetal acids in the preparation of effervescing draughts.

NITRATE OF POTASSA—Saltpetre.—This important salt is found abundantly as a natural product, usually associated with the nitrates of lime, magnesia, *et cetera*. It is obtained in a state of purity by decomposing carbonate of potassa by nitric acid. The solution by evaporation deposits crystals of the pure salt. It may be obtained also from the saltpetre of commerce, by pounding the latter, moistening it with one-sixteenth of its weight of nitric acid and a small quantity of water, evaporating the liquid to dryness with constant stirring, and repeating the process if the salt still contains chlorine.

Properties.—Nitrate of potassa— KO, NO_3 —is dimorphous. Its ordinary form belongs to the right prismatic system. More rarely, the crystals are obtuse, flattened rhombohedrons. Under both conditions it contains no combined water, but its crystals are never quite free from water lodged mechanically within them; and hence, on heating, decrepitation ensues. The taste of this salt is saline, accompanied with a sense of coolness. It is soluble in seven parts of water at 60° , and in an equal weight at 212° . At 616° it undergoes the igneous fusion, and at a strong red heat is completely decomposed with evolution of oxygen and nitrogen gases, leaving a mixture of potassa and peroxide of potassium. When mixed with combustible matter and heated, or when thrown in a state of fusion on some of the metals, rapid oxidation takes place at the expense of the oxygen of the nitric acid.

The saltpetre of commerce is derived principally from the East Indies, where, as also in Persia, Egypt, and Spain, it appears as an efflorescence on the surface of the soil. In some other countries, as the coast of the Adriatic, in Ceylon, North America, Africa, and Teneriffe, it is found on the walls of natural caverns formed in limestone rocks, and which contain also felspar and magnesia. It is also found widely distributed in some parts of Hungary, but in no case extending to any great depth below the surface of the ground, nor even to such a depth as the air cannot penetrate. Its appearance on the surface of the ground is explained by its ready solubility in water, as when its solution, in obedience to the law of capillary attraction, rises to the surface, the liquid is vaporized by the action of sun and air, and its place is immediately occupied by a fresh portion from below, which disappears in the same manner, until at last an incrustation of the salt is formed of considerable thickness, either in solid crystals, or as an effloresced mass.

Exudations containing saltpetre are not unfrequently met with upon new walls, and also, under certain cir-

cumstances, on old walls. Thus, in densely-populated towns, where the excrements of beasts of burden, refuse from slaughter-houses and from other trades of a similar kind, the water from the houses, the refuse of markets, *et cetera*, mix with the fluid in the drains, and are in a constant state of putrefaction—the coating of mortar on external walls, and especially near the base, gradually becomes covered with a white crystalline efflorescence, and the phenomenon is known as saltpetre rot. Indeed, whenever either accidentally or purposely a strong base, as lime, magnesia, or potassa, comes in contact with decaying vegetal or animal nitrogenous matters in presence of moisture, nitric acid is always generated, and, combining with the bases, produces nitrates; and these by contact with a potassa salt readily yield nitrate of potassa. The principle was, indeed, formerly extensively applied to the production of this salt.

Formation of Saltpetre—Nitrification.—Concerning the production of saltpetre, various theories have been from time to time promulgated, each of which has had large numbers of supporters, eminent for extensive chemical knowledge. GLAUBER, and subsequently STAHL, occupied themselves with this subject. About a century after the investigations of the latter chemist, LAVOISIER published a theory of the process; and since then, amongst others, KUHLMANN, THOUVENEL, THÉNARD, LONGCHAMP, GAY-LUSSAC, and LIEBIG, have devoted a considerable share of attention to the subject. The whole explanation of the process hinges upon the source of the elements of the nitric acid, and more especially upon the source of the nitrogen. The theory first published by LONGCHAMP supposes direct union of the nitrogen and oxygen of the atmosphere to be induced by electricity; and the nitric acid thus produced being brought to the ground in rain, combines with potassa and other bases capable of being converted into saltpetre by the action upon them of potassa salts. In reply to this, it may be observed that although, as first observed by CAVENDISH, lightning, in passing through the air, certainly induces combination of the elements of nitric acid, still this action is so limited, and of such rare occurrence, that its adoption as an explanation of the formation of saltpetre is quite inadmissible. LONGCHAMP, subsequently convinced of the untenability of his theory, adopted another one, in which he was supported by Dr. JOHN DAVY, PROUST, and others. This latter ascribes the union of the two elements to an action excited by the porous mineral constituents of the soil, similar to that of platinum black. The advocates of this view cite in defence of it the following experiments:—When earth forming nitre is freed from all its soluble salts by lixiviation, and is then exposed for several years to the action of the air, it yields a second crop of nitre, and these crops may be obtained three or four times in succession, although in different proportions. The supporters of this theory, supposing that all bodies containing nitrogen are removed by the first lixiviation, contend, therefore, that the nitrogen of the nitric acid subsequently produced, must have been derived from the air. That this conclusion is not justified by the circumstances of the case, was shown by GAY-LUSSAC, who, having estimated the amount of substances containing nitro-

gen, and compared this with the quantity of nitric acid actually generated, found that the proportion of the latter always corresponded with the quantity of nitrogenous matter present in the mixture, and that the yield of saltpetre was increased or diminished by an augmentation or decrease in the quantity of nitrogenized matters added. The conclusion that nitric acid is formed in such a case at the expense of atmospheric nitrogen, is, therefore, not in any way confirmed; indeed all experiments on the subject completely contradict the assertion that nitric acid may be generated in mixtures of earth destitute of nitrogenous matter. Considering, however, that nitrogenized organic bodies receive their nitrogen from the atmosphere in the form of ammonia, the primary origin of the nitric acid of saltpetre must be the ammonia of the atmosphere; and, in addition, it may be affirmed that ammonia is not only the ultimate source, but that it is also the immediate source of nitric acid; and hence the production of the latter may be expected wherever the ammonia and the conditions for its oxidation are found united. The truth of this theory is confirmed by the experiments of MARTIGNY, who found ammonia which had been confined with air over milk of lime, converted after six months into nitric acid; by those of KUHLMANN, who obtained a large quantity of nitric acid where a mixture of sulphate of ammonia, sulphuric acid, and bichromate of potassa, peroxide of manganese, or lead, were heated together; and by DUMAS, who has shown that when a current of moist air, mixed with ammonia, is passed over chalk moistened with a solution of potassa, at a temperature of 212° , there is formed after some time a considerable quantity of nitrate of potassa.

If, therefore, nitric acid is derived directly from the oxidation of the ammonia of putrefying organic matters, it appears probable that wherever the necessary bases are present in admixture, for fixing the acid, there saltpetre would be found. But, as in many other cases of decomposition, all the necessary conditions for the exertion of chemical affinities may be prepared, and yet the action will not ensue unless some impulse be given from without. This impulse proceeds most generally and energetically from some chemical action already in the course of operation. As has already been stated, the experimental conversion of ammonia into nitric acid has only succeeded at a high temperature or by the intervention of a free base, neither of which conditions frequently occurs in nature. The impulse which decomposing bodies can thus communicate, is, however, in all probability, sufficiently powerful to give rise to the formation of saltpetre at ordinary temperatures, and the time allowed for its production in nature very much exceeds the duration of ordinary experiments. It is highly probable that ammonia also plays a double part in the formation of saltpetre; first, in surrendering its elements to oxidation, and then also in saturating the acid, producing nitrate of ammonia. This salt then coming in contact with earthy and alkaline carbonates, decomposition ensues, nitrates of the earths or alkalis, and carbonate of ammonia being produced; thus $\text{N H}_4 \text{ O, NO}_5 + \text{MO, CO}_2 = \text{MO, NO}_5 + \text{NH}_4 \text{ O, CO}_2$. The ammonia therefore not only parts with its elements for the production of nitric acid, but also acts as a

carrier of the acid to a stronger base. The ammonia now become carbonate, and this salt possessing basic properties, it resumes its functions in a higher degree on account of the presence of moisture.

As already noticed, saltpetre is found in several countries, as a saline efflorescence on the surface of the earth. In India, the district of Tirhút is the most productive of this salt, and it is always more abundant in those parts containing a redundancy of carbonate of lime. An average sample of the soil analysed by STEVENSON, gave the following results:—

		Per centago.
Matter insoluble in acids,.....		50.0
Carbonate of lime,.....		44.3
Matter { soluble { in water, {	Sulphate of soda,.....	2.7
	Chloride of sodium,.....	1.4
	Nitrate of lime,.....	0.9
	Nitrate of potassa,	0.7
		100.0

The process for the extraction of the saltpetre is commenced by scraping off the surface from old mud heaps, mud buildings, waste grounds, *et cetera*, where the saltpetre has developed itself in a thin white efflorescence resembling frost rind. This saline earth being removed to the factories, is subjected to the process of lixiviation. This is effected in a large mud filter, lined on the inside with stiff clay. The filter has a false bottom of bamboo, covered with close-wrought grass mats, on which are placed vegetal ashes. Upon these the saline earth is laid. Water is then added to remove the soluble salts, and the solution thus obtained, filtering through the mats, drops into the empty space between the real and false bottom, and is conveyed away into an earthen receiver. In its passage through the wood ashes, the carbonate of potassa contained in the latter reacts upon the nitrate of lime, producing nitrate of potassa and carbonate of lime: thus $\text{Ca O, NO}_5 + \text{KO, CO}_2 = \text{Ca O, CO}_2 + \text{KO, NO}_5$. The solution is now evaporated in earthen pots, filtered, and put aside to crystallize. The impure salt thus obtained is termed *dhouah*. It contains from forty-five to seventy per cent. of nitrate of potassa. This is redissolved and recrystallized by the native merchants, and when thus purified is known by the natives as *kalmee*.—Stevenson.

In Ceylon the nitrous efflorescence on the walls of the natural caverns is detached, during six months of the year, with picks, together with a small portion of the rock, which latter, as it contains felspar, is doubtless the source of the potassa. The fragments are pounded, mixed with an equal portion of wood ashes, and water is poured upon the mixture. The earthy nitrates yield their acid to the potassa contained in the ashes, and the earths are precipitated as carbonates of lime and magnesia. The clear decanted lie, containing, besides the nitre of the rock, also that formed by the decomposition of the earthy nitrates, is evaporated in pits, exposed to the sun, and afterwards in pans by means of artificial heat. The crude saltpetre which crystallizes on cooling, is then fit for exportation.

During the period of the great war with France, at the end of the last and the commencement of the present century, the immense quantities of saltpetre, required for the manufacture of gunpowder, were produced in that country by an artificial process. The

great difficulty experienced by the government of that country, in obtaining the necessary supply of this indispensable material of warfare, induced them to offer a prize for the best treatise upon the principles of its production, and the best method of putting them in practice. The number of competitors was sixty-six. From the most valuable of these treatises, a process of manufacture was deduced, which, though tedious and costly, was perfectly successful, the execution of which was intrusted to BERTHOLLET, one of the most eminent chemists of that period, and who traversed the nation from one extremity to the other, giving instructions as to the mode of procedure. The process, of which the following is an outline, though no longer practised to any considerable extent, is of great importance. Animal refuse of all kinds is mixed with old mortar, or slaked lime and earth, and the mass placed in heaps, and protected from rain, is freely exposed to the air. From time to time these heaps are turned over and watered with fluids containing putrid nitrogenous matters, such as stale urine, cesspool liquors, or waters in which animal flesh or cheese has been soaked or washed. After a certain period a white mouldy appearance is observed on the surface of the heap, consisting of the nitrates of alumina, lime, magnesia, *et cetera*. When the process is at an end, the earth is said to be ripe, and is lixiviated with water in troughs in double bottoms, using only as much liquid as is necessary for the extraction of the salts. To the lie thus obtained, potashes, sulphate of potassa, or chloride of potassium is added in sufficient quantity to convert the nitrates of the earths into nitrate of potassa. If sulphate of potassa is used, milk of lime is also added to decompose the sulphate of magnesia that will be formed. After deposition of the heavy precipitate, the clear solution containing nitrate of potassa, chlorides of potassium and sodium, and a little sulphate of lime, is drawn or siphoned off, concentrated by boiling, and by repeated crystallization the salt is obtained comparatively pure.

Besides solid and liquid animal refuse, some vegetal substances are also applicable to the production of saltpetre. Thus, several weeds belonging to the families *solanaceæ*, *euphorbiacæ*, and *fungi*, pea, bean, and Indian corn straw, are especially valuable. In some countries, as for instance in Sweden, where saltpetre is one of the government taxes, vegetal matters are employed either with or without animal refuse. In the construction of the heap, the vegetal substance is first spread out upon a layer of earth; upon these the other solid matters are laid to a height of some feet, and the whole is covered with a second layer of earth. This heap is watered from time to time with urine, in quantity just sufficient to keep it moist throughout. During the summer, the heap, which has decayed to a uniform mass, is turned over once weekly, and in winter, once monthly, care being taken to keep the whole as loose as possible.

In Switzerland the earth below the flooring of stables, or in the neighborhood of dunghills, or in the cellars of dwelling-houses, where the remains of vegetal or other organic matters have been left to decompose, is the material used for the production of saltpetre. In Prussia a peculiar continuous process is practised. Tho

heaps are constructed with perpendicular sides; that opposed to the wind is simple and flat, while the opposite one forms a series of steps down to the bottom; on each step is a gutter, which carries back the excess of liquid poured upon it to a cistern. In this arrangement, the watering takes place at the back, while the evaporation proceeds principally at the sides exposed to the wind, so that the saltpetre is gradually drawn towards the latter part, whence it is removed, and an equal quantity of fresh earth is added behind. The great advantage of this method is that a heap is never totally destroyed, and the great difficulty experienced in the commencement of the process of nitrification is entirely removed. The preparation of saltpetre, by decomposing nitrate of soda, is pursued in some localities where potashes can be obtained at a low price. In this case the change is very simple, nitrate of potassa and carbonate of soda being produced. Thus, $\text{Na O, NO}_3 + \text{KO, CO}_2 = \text{Na O, CO}_2 + \text{KO, NO}_3$. All that appears difficult in this process is the removal of the carbonate of soda, but, as remarked by KNAPP, a greater difficulty arises from the presence of chloride of sodium in commercial nitrate of soda; for as soon as a little more potashes are added than correspond with the quantity of pure nitrate of soda, the excess decomposes chloride of sodium to no purpose; and in the opposite case the product is contaminated with portions of undecomposed nitrate of soda.

Purification.—The crude saltpetre as obtained by the above processes, as well as the rough salt imported from Ceylon and the East Indies, always contains more or less impurity, which may be organic, that is, vegetal or animal matter, or inorganic, as other alkaline and some earthy soluble salts, or both. The foreign matters most frequently present, and in the largest proportion, are the chlorides of potassium and sodium, in some cases exceeding twenty-five per cent. of the crude salt. These latter are of all impurities the most objectionable, and the most difficult to remove. The process of separation most frequently practised depends upon the fact that the solubility of nitre rapidly increases with elevation of temperature, while that of the two chlorides remains nearly constant. A roomy copper boiler is the one most frequently employed. A rough estimation of the amount of impurity present having been previously made, and the solubility of pure nitrate of potassa being known, namely, three parts to one of water, the crude salt is added to the boiling water, until as much nitrate of potassa is present as can be dissolved, the heat at the same time being increased until the saturated solution also enters into ebullition. The solution is now kept constantly stirred, and the scum which collects on the surface is removed. A large proportion of the chloride of sodium subsides, and is scooped out from the bottom of the pan. A further quantity of water is then gradually added, amounting to two-thirds of that originally employed, and afterwards an aqueous solution of common glue, containing one pound of the latter to every ton and a half of crude saltpetre operated upon, and the whole is again boiled and well agitated. The glue thus diffused through the liquid enters into combination with the organic extractive matter present,

and carries it to the surface in the form of scum, which is carefully removed; and after boiling for some time, the solution is perfectly clarified. The whole is then allowed to stand at rest for twelve hours, the heat being continued at about 190° , so as to prevent crystallization of the salt, which, if allowed, renders the after process much more tedious. The supernatant liquid is now carefully drawn off from the deposit of common salt and other matters into the crystallizing pan. This latter is a shallow copper vessel, the edge of which is firmly secured to a platform of oak. It is formed of two inclined planes, so arranged that the deepest point is at one of the narrow sides. As the liquor cools, the crystals quickly form, and if the liquor is left tranquil, they are of large size and clustered together. If, however, the liquid be constantly agitated while in the act of cooling, the salt separates in fine crystalline needles, termed *saltpetre flour*, and as it forms, is drawn out of the lie towards the top of one of the inclined planes of the pan, where it remains until the mother-liquor has drained from it. This method of crystallization, first recommended by BEAUMÉ and LAVOISIER, is far preferable to the old process in which the salt is allowed to separate from the tranquil liquid; as in this case, owing to the formation of larger crystals, and in clusters, a much greater proportion of mother-liquor is retained, and a second solution and crystallization is required to render the salt sufficiently pure for commercial purposes. The salt separated as above, when sufficiently dry, can contain only a very small quantity of mother-liquor, and consequently, also of the impurities therein contained. To effect the removal of the last traces of these, the crystalline mass is next washed in tubs provided with a false bottom drilled with holes. These tubs are filled completely with the salt, the latter being heaped up some inches above the rim. The washing-liquor is a saturated solution of *pure* nitrate of potassa, which, although it dissolves other salts that may be present as readily as would be the case with pure water, of course can have no effect upon the saltpetre. This liquor is poured upon the salt, so as thoroughly to wet the mass, and by means of a plug, is prevented from running off for a period of three hours, after which the plug is removed, and the salt well drained. This operation is again repeated, in this case with pure water, and these washings constitute the solution of nitrate of potassa which is employed for the first washing of a fresh portion of the salt. After being well drained, for which a period of some days is required, the saltpetre flour is dried with constant agitation in a pan economically heated by the flue of the boiler fire.

Refraction of Saltpetre.—A considerable proportion of the crude saltpetre of commerce always consists of foreign matters, and as its value is solely dependent upon the amount of pure nitrate of potassa which it contains, it is important to have some readily available means of ascertaining with accuracy the quantity of the pure salt, or, which answers the purpose equally well, the amount of impurities contained in a given sample. The determination of these impurities, or the loss which results from the purification or refining of saltpetre, is technically termed the *refraction*.

The foreign matters usually met with in crude saltpetre are chlorides of potassium, sodium, and magnesium, sulphates of potassa and lime, nitrate of soda, water, and traces of organic matter. The accurate quantitative analysis of such a mixture of salts is not a very easy problem; and yet their separation is essentially necessary, to render saltpetre available for the purpose to which it is almost wholly applied, namely, the production of gunpowder.

Several processes have from time to time been suggested for the refraction of saltpetre, many of which are however of little value, though even now extensively practised both in this and other countries. Whatever method be adopted, especial care must be exercised to procure a fair average sample of the salt to be examined.

The method of refraction principally employed in France, is that introduced by RIFFAUT, which, besides being very tedious, gives only approximate results. It consists in washing a weighed quantity of the dry crude salt, with a saturated aqueous solution of pure nitrate of potassa. This, although it cannot extract nitrate of potassa from the sample, effects the removal of all foreign soluble salts. When these are extracted, the salt remaining on the filter is dried and weighed, and the amount of loss sustained by the original sample is taken to represent the amount of impurity present. This method is liable to so many sources of error, as to render it quite inapplicable in cases where even a tolerable degree of accuracy is required. Under the most favorable circumstances, it indicates from one to three per cent. more nitrate of potassa than is actually present in the sample.

A better method is that suggested by GAY-LUSSAC, but which, as it requires great care and dexterity in its execution, is unfitted for practical use, except to the experienced chemist. In this process the nitrate of potassa is converted into carbonate by fusion with charcoal; and the quantity of potassa contained in the new salt is estimated exactly as directed when treating of the valuation of potashes, or ALKALIMETRY. Every forty-seven grains of potassa found, indicate one hundred and one grains of nitrate of potassa contained in the sample under examination.

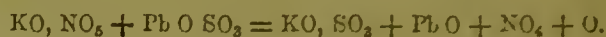
Various other processes are practised by different analysts, in which the amount of nitrate of potassa contained in a given sample of crude saltpetre is deduced from the quantity of nitric acid present, and therefore they consist in the determination of this acid by any available means. Amongst them the method of GOSSART, as modified by PELOUZE, is the most frequently applied. This consists in the determination of the amount of protoxide of iron converted to the state of sesquioxide, by a weighed portion of the salt to be examined. The theory of this reaction is represented by the following equation— $6 \text{ Fe Cl} + \text{KO, NO}_5 + 4 \text{ H Cl} = 4 \text{ HO} + \text{K Cl} + \text{NO}_2 + 3 \text{ Fe}_2 \text{ Cl}_3$. That is to say, every one hundred and sixty-eight parts, or six equivalents of iron converted from the state of protochloride to that of sesquichloride, represent fifty-four parts, or one equivalent of nitric acid. The process is conducted as follows:—Thirty-one grains of pianoforte wire are dissolved in about fifteen hundred

grains measure of concentrated hydrochloric acid; to this is now added 18·7 grains of the saltpetre to be examined, and the flask containing the mixture is immediately closed and heated till the liquid boils. The latter quickly assumes a brown color, and the dense vapors of hydrochloric acid and nitric oxide which issue from the flask prevent the access of air, which, if allowed to come in contact with the mixture, by its action upon the nitric oxide, which it converts to nitrous acid, would oxidize a certain quantity of iron, and thus render the estimate of the nitrate of potassa apparently higher than it really is. When the solution has become of a clear yellow color, and perfectly transparent, the flask containing it is removed from the source of heat, and the liquid is transferred to a convenient vessel and diluted with two pints of water. A solution of permanganate of potassa of known strength is now cautiously added from a graduated burette, constantly agitating the mixture; and as soon as the latter acquires a faint rose-red tint, the addition of permanganate of potassa is discontinued, and the quantity employed to sesquioxidize the iron read off on the burette. The proportion of nitric acid contained in the sample is now readily deduced as follows:—Suppose the test solution of permanganate of potassa employed to be of such strength, that one hundred alkalimetric measures are required to sesquioxidize fifty grains of iron; and that fourteen divisions were required to complete the oxidation of the iron left in the state of protochloride after treatment with the saltpetre as above directed, the amount of protochloride corresponding to the fourteen divisions is at once found by a simple calculation—for if one hundred measures of the solution of permanganate are required to sesquioxidize fifty grains of iron, fourteen measures will suffice for seven grains. If this quantity be now subtracted from the thirty-one grains of iron originally employed, the remaining twenty-four grains represent the quantity sesquioxidized by the 18·7 grains of saltpetre employed. Now, as thirty-one grains of iron require 18·7 of pure nitrate of potassa to effect its complete oxidation, twenty-four grains of iron will require 14·48 of pure nitrate; this represents the amount contained in the 18·7 grains submitted to examination, and by the calculation, as $18\cdot7 : 14\cdot48 :: 100 : 77\cdot43 =$ the per centage amount of pure nitrate of potassa contained in the sample.

In the process recommended by STEIN, the proportion of pure nitrate of potassa contained in a given sample of saltpetre is estimated by the amount of arsenious acid which it can convert to the state of arsenic acid. This method, though it gives accurate results, owing to the length of time required to perform the analysis, is inapplicable for ordinary commercial determinations, and will, therefore, not be further considered.

In the Editor's laboratory the method of refraction usually pursued is that recommended by ZENNER. The process for the determination of the nitric acid depends upon the ease with which the nitrates of the heavy metallic oxides are decomposed by heat. It is conducted as follows:—From ten to fifteen grains of the salt to be examined are introduced into a wide-bottomed porcelain crucible, and, after fitting with a

lid, the latter is heated until the salt fuses smoothly and without bubbles. The loss of weight in this operation represents the amount of water present. A quantity of freshly-dried powdered sulphate of lead, amounting to eight or ten times the weight of the saltpetre, is then placed upon the latter, and the crucible is again weighed. It is now placed over the lamp and gently heated, when decomposition ensues as follows:—



As soon as the crucible becomes hot, red-colored fumes of nitrous acid are seen to escape from under the lid; when this has ceased, and no more can be detected by the smell, the lid is lifted. Should any nitrous vapors remain in the crucible, the heat is continued a little longer. After cooling, the crucible is weighed, and the loss sustained gives the amount of nitric acid contained in the salt. Every fifty-four grains of nitric acid thus liberated represent one hundred and one grains of pure nitrate of potassa. This process is recommended not only for its accuracy, but also for the simplicity of its manipulation, and the short time required for its performance. The presence of chlorides, sulphates, or earthy matters does not in the slightest degree interfere with its application; but should the total amount of impurities exceed five per cent., it is necessary to mix the saltpetre with about four or five times its weight of the lead-salt in a small mortar, and after having transferred the mixture to the crucible, to rinse the mortar with small quantities of the reagent, which are then placed on the top of the first in the crucible.

The quantity of sulphate of potassa contained in saltpetre is determined by taking a weighed portion, dissolving in water, acidulating the solution with nitric acid, and adding nitrate of baryta as long as a precipitate is produced. Every 116·6 grains of sulphate of baryta thus obtained represent eighty-seven grains of sulphate of potassa. The amount of chloride of potassium is estimated by adding to a solution of another portion. nitrate of silver. Every 143·5 grains of chloride of silver produced, indicate 74·5 grains of chloride of potassium. Lastly, the quantity of insoluble matter is determined by dissolving a given weight of the sample in water, filtering, washing, and drying the insoluble residue, and weighing it.

Should the saltpetre under examination be contaminated with chloride of sodium, or, still more detrimentally, by nitrate of soda, the above methods of estimation do not give accurate results. In this case, it is necessary to determine the respective quantities of the two bases—potassa and soda. This is effected most conveniently by converting these bases into anhydrous sulphates, and weighing. The dry mass is then redissolved in water, and the sulphuric acid estimated by precipitation as sulphate of baryta. Now, as one hundred parts of sulphate of potassa give one hundred and thirty-four of sulphate of baryta, whilst the same amount of sulphate of soda gives one hundred and sixty-four parts of the barytic salt, it is evident, that if the weight of the mixed sulphates of the alkalis, together with that of the sulphate of baryta, be known, the respective quantities of potassa and

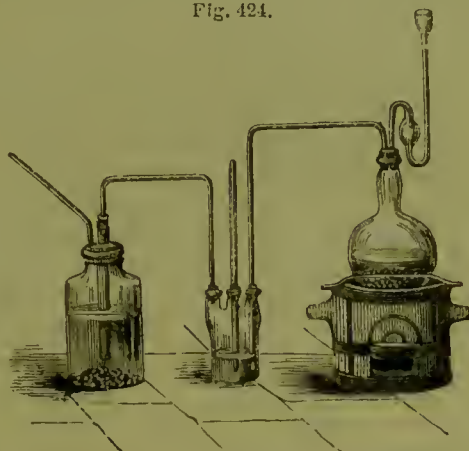
soda may be easily ascertained. Thus, if a larger quantity of sulphate of baryta be obtained than the ratio 134 : 100, the excess would be due to the salt of soda, from which the quantity of soda existing in the sample in the state of nitrate may be calculated, since every one hundred parts of sulphate of soda represent 119.7 of the nitrate.

The principal use of saltpetre in the arts, is in the production of gunpowder, for an account of which the reader is referred to page 335, *et sequitur*. In the East Indies it is employed for the preparation of cooling mixtures. On account of its powerful antiseptic properties, it is much used in the preservation of meat and animal matters in general. In the laboratory of the chemist, nitrate of potassa is chiefly employed as an oxidising agent. It is used also in the preparation of lucifer matches. The physiological effects of nitrate of potassa are, in small doses, diuretic and sedative; in doses of from half an ounce to one ounce, it is poisonous, exciting spasms, vomiting, bloody stools, convulsions, and in many cases death.

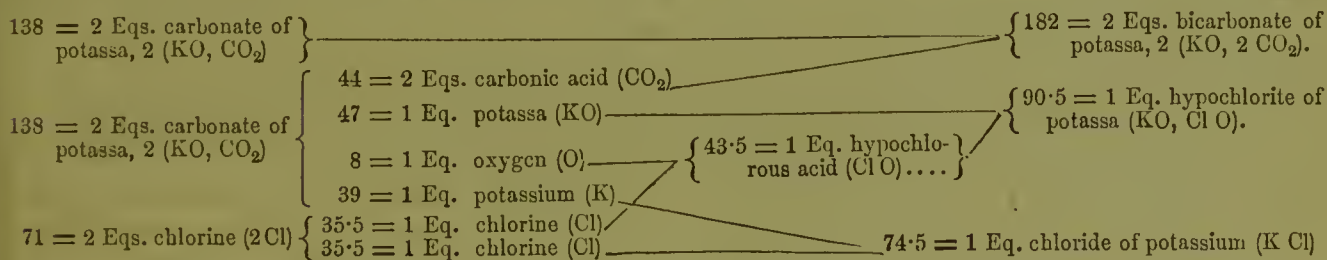
CHLORATE OF POTASSA.—This salt, when first prepared, was confounded with the one just described, but was distinguished as a peculiar salt by BERTHOLLET in 1786. The Editor finds it is most economically prepared by exposing equivalent proportions of carbonate of potassa and hydrate of lime to a current of chlorine. During the absorption of the gas the mass becomes hot, and evolves water; when saturated, it is gently heated to complete the decomposition. The fol-

lowing equation represents the change: $6 \text{ KO}, \text{CO}_2 + 6 \text{ Ca O} + 6 \text{ Cl} = 5 \text{ K Cl} + 6 \text{ Ca O}, \text{CO}_2 + \text{KO}, \text{Cl O}_5 + 6 \text{ H O}$. By treatment of the mass with water, the carbonate of lime is separated, and the chlorate of potassa is then freed from the more soluble chloride of potassium by evaporation, and repeated crystallization. The usual method of preparing this salt is by passing chlorine slowly through a solution of carbonate of

Fig. 424.

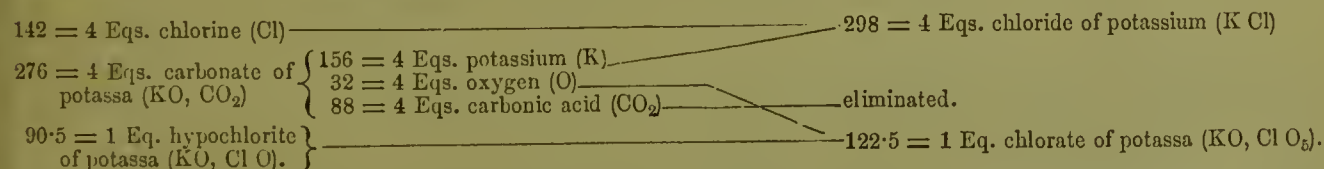


potassa. The apparatus employed is shown in Fig. 424. The gas is absorbed with evolution of carbonic acid. When this has ceased, the solution is set aside to crystallize, and the salt obtained is purified as above directed. In this process the subjoined changes take place:—



In proportion as the quantity of chlorine increases, the bicarbonate becomes decomposed, carbonic acid is eliminated, and an additional quantity of hypochlorite

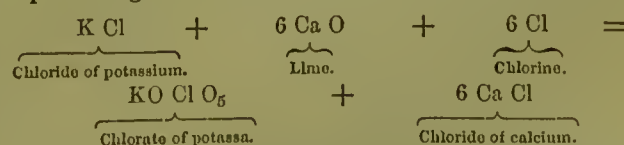
of potassa is produced. When the solution is strongly charged with hypochlorite, the action of the chlorine on the potassa salt is changed. Thus:—



The residual liquor, after crystallization of chlorate of potassa, contains, besides a small proportion of this salt, a considerable quantity of hypochlorite of potassa and chloride of potassium.

Manufacture.—Chlorate of potassa is now produced on a large scale by the following method, which has been found to answer better than any other. One part of chloride of potassium and two parts of hydrate of lime are reduced with water to a thin cream, and chlorine gas—prepared in the ordinary way from binoxide of manganese and hydrochloric acid—passed through the menstruum till it assumes a *pinkish* color, which is due to the formation of traces of hypermanganic acid.

A little manganese passes over during the operation, and when no more chlorine is required for the alkaline bases, water is decomposed and hypermanganic acid produced. The annexed equation represents the principal change:—



The vessel holding the solution is of any convenient form, and is provided with agitators of all shapes and sizes, depending upon the whim or caprice of each

manufacturer. It is connected with a similar one containing a fresh charge of the same materials, by means of a waste-pipe, through which all the escaping gas passes to be there absorbed. When the liquor in the former is ready to be drawn off, the gas is made to enter the latter, and the connecting-pipe between the two eisterns takes the unabsorbed chlorine to the first vessel, which, when empty, is re-filled immediately, so that very little time or gas is lost. The saturated liquor is, when drawn off, evaporated to 34° Twaddell, and the mother-lie to 46° , if two crops of crystals are desired; if only one, then the menstruum is at once evaporated to 60° . The crystals, after being well washed, are drained on a cone having a small aperture at the bottom, and are afterwards dried upon iron plates heated by steam. The chloride of calcium is the only other compound present. Some manufacturers re-crystallize them, so as to produce a first-rate article. The principal manufacturers of this salt are, ALBRIGTS of Birmingham, GAMBLE of St. Helen's, JAMES MUSPRATT and SONS of Liverpool, and FREDERIC MUSPRATT of Woodend, near Warrington, Lancashire. The annual production is nearly five hundred tons. The principal use to which it is applied are in bleaching, making lucifer matches, and for pyrotechnic purposes.

The Editor thinks that some means might be adopted for using this salt in the bleaching of palm oil, *et cetera*, instead of the chromate; it is cheaper, and it contains more of available oxygen.

Properties.—Chlorate of potassa— KO, ClO_3 —is a colorless, transparent, anhydrous, crystalline salt, having a glassy lustre. The crystals are oblique rhombic prisms. The taste of the salt is cooling and austere. If it be triturated, it appears phosphorescent. When heated to between 400° and 500° , it decrepitates and fuses; at a stronger heat, it loses the whole of its oxygen, leaving a residue of chloride of potassium. According to GAY-LUSSAC, it is soluble in thirty-three parts of water at 32° , in seventeen at 59° , and in five parts at 212° . It is slightly soluble in alcohol. Its action upon many combustible bodies is very energetic, and when rubbed with charcoal, sulphur, and phosphorus, the mixture inflames and explodes. Its principal use is in the manufacture of lucifer matches, and percussion powder for gun caps. It was proposed by BERTHOLLET as a substitute for saltpetre in the manufacture of gunpowder, and the attempt was made at Essone in 1788; but no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration, than a violent explosion took place, which proved fatal to several persons. Chlorate of potassa has also been used in medicine for imparting oxygen to the system; but, curious to say, as shown by WÖHLER, it passes off by the kidneys unaltered, and according to CHRISTISON, has no physiological or therapeutic action whatever.

CHROMATE OF POTASSA.—This salt, though much more important as a compound of chromium than of potassium, yet requires to be noticed under this head. The metal, *chromium*, so called from its tendency to produce colored salts, the name being derived from the Greek word signifying color, was discovered by VAUQUELIN in 1797, in the examination of red chromate of lead from Siberia. The most important native compound

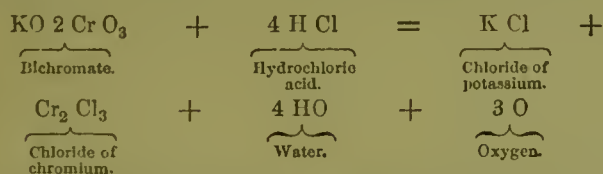
of this metal is a combination of oxide of chromium and iron, commonly termed chromate of iron, which is found abundantly at Unst in Shetland, and in other parts of Europe and America. DUMAS directs chromate of potassa to be prepared from the double oxide of chromium and iron— $\text{FeO} + 2\text{Cr}_2\text{O}_3$ —as follows:—The ore is to be pulverized and mixed with an equal weight of nitrate of potassa, and the mass gradually heated to redness. In this operation, chromate, silicate, aluminate, and occasionally manganate of potassa are produced, and the oxide of iron is set free. The soluble salts contained in the mixture are extracted by washing, and the residue, which still contains chromium, is digested with hydrochloric acid—which dissolves the oxide of iron and alumina—and again heated with nitre as before. The aqueous solution is then exactly neutralized with nitric acid, and by evaporation the alumina and silica are separated. The crystals of chromate are then freed from those of nitrate of potassa, and purified by recrystallization. It is important in the preparation of this salt to use a very small proportion of saltpetre, so that the whole of the alkali may combine with chromic acid, and constitute a neutral chromate; to oxidise the whole of the chromium, the fusion is repeated with those portions of the ore unattacked by the first operation. The process for the manufacture of chromate of potassa has lately been rendered more economical by the substitution of lime for the nitrate in the preliminary calcination. A mixture of the chrome iron ore and lime or chalk in very fine powder, being calcined, oxygen is absorbed, and a chromate of lime formed, which is extracted from the mass by water. The solution is then decomposed by means of a potassa salt, and the chromate of potassa produced is separated from the calcareous compound by crystallization in the usual manner.

Properties.—Chromate of potassa— KO, CrO_3 —is deposited from a concentrated solution in small prismatic anhydrous crystals. It has an unpleasant metallic taste, and an alkaline reaction. It is very soluble in boiling water. At 60° this liquid dissolves half its weight of the salt. In alcohol it is insoluble. Its coloring power is so great, that one part gives a distinctly yellowish hue to forty thousand parts of water. As met with in commerce, chromate of potassa frequently contains sulphate; the sophistication may be detected by acidifying a solution of the salt with hydrochloric acid, and adding chloride of barium, when, if a sulphate be present, insoluble sulphate of baryta precipitates. The principal use of this salt is in the preparation of the chromates of lead, zinc, *et cetera*, which are extensively employed in painting, and the former also as an oxidising agent in the ultimate analysis of organic substances.

BICHROMATE OF POTASSA.—This salt is of great importance in the arts and manufactures, and especially in calico printing. By a reference to the article on DYEING, Vol. I., page 643, *et sequitur*, the reader will become acquainted with the variety of purposes to which it is applied in this most useful and beautiful art. The principal manufactories of the bichromate or *chrome* are at Glasgow. It is obtained from the salt last described by adding a sufficient quantity of acid—usually sulphuric—to impart to the solution a sour

taste. The mixture is then set aside for a few days, when deep orange-red crystals are deposited. The change may be thus represented— $2 \text{ KO}, \text{ Cr O}_3 + \text{ SO}_3 = \text{ KO}, 2 \text{ Cr O}_3 + \text{ KO}, \text{ SO}_3$. The use of nitric acid is much to be preferred; as if sulphuric acid be employed there is considerable difficulty in separating the sulphate from the chromate, while if nitric acid be employed the nitrate of potassa produced, being much more soluble than the bichromate, admits of more easy separation. For the same reason, if acetic acid be taken the salt is obtained in a still greater degree of purity. Owing to the higher value of these acids, however, they will probably never entirely supersede sulphuric acid in this manufacture.

Properties.—Crystallized bichromate of potassa— $\text{KO}, 2 \text{ Cr O}_3$ —has the form of quadrangular prisms and tables, is anhydrous, permanent in the air, and of a beautiful orange-red color. The crystals are soluble in about ten times their weight of water at 60° , and much more so in boiling water. When heated to redness, they fuse without decomposition into a transparent red liquid, which on cooling concretes to a crystalline mass, and, owing to the unequal contraction of the crystals, afterwards crumbles to powder. At a white heat a portion of the chromic acid is reduced to a lower oxide, and the residue consists of sesquioxide of chromium, and neutral chromate of potassa. When this salt is dissolved in hydrochloric acid, and the solution boiled, a salt is produced containing an equivalent of chloride of potassium united to two of chromic acid— $\text{K Cl}, 2 \text{ Cr O}_3$ —in which the chloride of the alkaline metal acts as a base to the chromic acid. According to GREGORY, both chromates of potassa have a very deleterious action on the system when their solutions are frequently brought in contact with the skin—producing sores which are painful and difficult to heal. Bichromate of potassa is occasionally employed in conjunction with chromate of lead as a source of oxygen in organic elementary analysis. The solution of both chromates is possessed of powerful antiseptic properties. Large quantities of this salt are used in the bleaching of palm oil as a source of oxygen, which is liberated as follows:



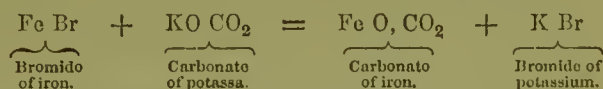
CHLORIDE OF POTASSIUM.—This salt may be prepared by inclosing potassium in chlorine gas, when the metal takes fire, burning even more brilliantly than in oxygen, and at the same time combination ensues between the two elements. It is formed also when potassa or its carbonate is dissolved in hydrochloric acid—in the case of the latter with evolution of carbonic acid. As, however, this salt is frequently obtained as a by-product in several chemical and pharmaceutical operations, it is seldom necessary to prepare it directly. As previously noticed, it is obtained in considerable quantities in crude saltpetre and in pearl ash, and exists also in the mother liquor of the chlorate of potassa. From these sources it may readily be obtained in a state of purity by successive crystallizations.

Properties.—Chloride of potassium— K Cl —is an anhydrous salt, the form of the crystal of which is cubic. It has a saline and slightly bitter taste; dissolves in three parts of water at 60° , and in a much less quantity of boiling water. It is insoluble in alcohol. When heated, it decrepitates, and at a red heat fuses without decomposition. At a very high temperature, in open vessels, it slowly volatilizes in the form of white fumes, but in a covered vessel may be intensely heated without perceptible loss. Chloride of potassium is a salt of great importance in the arts on account of the facility with which it is transformed into other salts of potassa; hence, its use in the decomposition of the nitrates of lime, *et cetera*, in the production of saltpetre. It is also equally valuable in the preparation of potassa alum.

IODIDE OF POTASSIUM.—This important salt, like the chloride, may be prepared directly by combining the two elements, by heating them in contact with each other. The various methods for procuring it on the large scale, its properties, actions, and uses in the arts, have been detailed under the article IODINE, to which the reader is referred.

BROMIDE OF POTASSIUM.—Bromine and potassium are contained in sea-water, but whether the bromine is in combination with potassium or with some other metal, as, for example, sodium or magnesium, has not yet been ascertained, so difficult is the problem.

The process of the London college is the one usually followed in the preparation of this salt. One ounce of iron filings, and afterwards two ounces of bromine, are added to one and a half pints of water, and the mixture is allowed to stand for half an hour, constantly agitating. A gentle heat is then applied until a greenish color is developed. A solution containing two ounces and one drachm of carbonate of potassa to a pint and a half of water, is then added, and the precipitate of carbonate of iron produced is removed by filtration; and by evaporation of the filtrate the salt is obtained in crystals. In this process a bromide of iron is first formed, which is then decomposed by the carbonate of potassa, thus:—

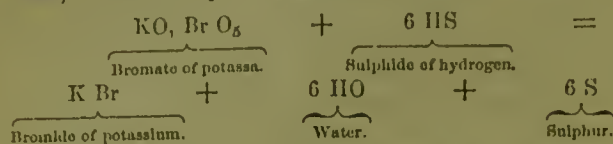


Another method of procuring this salt consists in adding to a hot solution of potassa, as much bromine as the liquid will dissolve. A brownish fluid is thus produced, through which sulphide of hydrogen is passed until it becomes colorless. Gentle is the heat then to be applied to expel the excess of the latter reagent, and the sulphur which has precipitated is removed by filtration. The filtrate on evaporation will then yield crystals of bromide of potassium. The action of bromine upon a solution of potassa is analogous to that of chlorine, as noticed under chlorate of potassa, and may be thus expressed:—



When sulphide of hydrogen is passed through a solution containing bromate of potassa, decomposition ensues, the hydrogen of the gaseous acid abstracts the

whole of the oxygen from the bromate, and, at the same time, the free sulphur precipitates, thus:—



The filtered solution contains, therefore, only bromide of potassium. Occasionally a modification of this latter process is employed, in which the oxygen of the bromate of potassa is removed by heating the salt to redness, instead of by the sulphide of hydrogen.

Properties.—Bromide of potassium—K Br—crystallizes in cubes or rectangular four-sided tables, has a sharp, pungent, saline taste, and is persistent in the air. When heated, it decrepitates, and at a red heat fuses without decomposition. It is very soluble in water, and slightly so in alcohol. At a red heat it is decomposed by chlorine, but not by iodine; and bromine is also disengaged in the cold by the mineral acids.

Adulteration.—Commercial bromide of potassium frequently contains chloride, and sometimes also iodide of potassium. The presence of the latter is most conveniently detected by the addition, to an aqueous solution of the salt, of protochloride of palladium, which in presence of iodide gives a brownish-black precipitate. Nitrate of protoxide cannot be substituted for the chloride of palladium, as in this case bromine is also precipitated. The most frequent adulteration, however, is with chloride of potassium, and yet the London college gives no test for the detection of this sophistication. The best method is that suggested by ROSÉ, and is conducted as follows:—The suspected salt is mixed with an excess of bichromate of potassa, and introduced into a tubulated retort with the addition of concentrated sulphuric acid, and a receiver is adapted, containing aqueous ammonia. On the application of heat, if the salt be pure, only bromine distils over, and the volatile alkali remains perfectly colorless. If, however, a chloride be present, *chloro-chromic* acid also passes over, and the ammonia becomes yellow; and in the solution chromic acid may now be detected by the production of a yellow precipitate, on addition of acetate of lead.

Physiological effects.—Bromide of potassium is a diuretic and cathartic. Like the preparations of iodine, mercury, *et cetera*, it appears to exercise that influence over the nutrition of the body designated by the terms, resolvent, alterative, and deobstruent. Under its continued use, PEREIRA states that enlargements of the spleen and liver, and swellings of the lymphatic glands have disappeared; and Dr. WILLIAMS is of opinion that it possesses unusual, if not specific powers, in the cure of diseases of the spleen. It has also been used advantageously in scrofulous tumors, and in bronchoccele.

CYANIDE OF POTASSIUM.—This useful salt is most advantageously prepared from ferrocyanide of potassium or yellow prussiate of potassa, which is to be carefully desiccated, and reduced to fine powder, eight parts of which are mixed with three parts of carbonate of potassa and one of charcoal, both in impalpable powder. This mixture is to be exposed to a strong red heat in a closed

iron crucible. After cooling, the mass is to be finely powdered, placed in a funnel moistened with a little alcohol, and then washed with cold water. The colorless strong solution of cyanide of potassium which passes through, is then rapidly evaporated to dryness in a porcelain basin and fused at a red heat. This salt, as obtained by ignition of the above ingredients, without the charcoal, usually contains a little cyanate, which, however, does not interfere with its use for forming and dissolving cyanides of gold and silver for the processes of voltaic gilding and plating.

The preparation of cyanide of potassium in a state of perfect purity, is always attended with difficulty, owing to the action of the carbonic acid of the air upon its solution, and the tendency of the menstruum itself to undergo spontaneous decomposition, even when secluded from the air. It is obtained in a state of great purity by adding absolute hydrocyanic acid, or a strong solution of this acid, to an alcoholic solution of potassa; a portion of the cyanide falls down as a white crystalline precipitate, which should be washed with alcohol and dried. An additional quantity may be obtained from the mother liquor by evaporation of the latter in a retort. Cyanide of potassium crystallizes in colorless cubes, which deliquesce in damp air, at the same time becoming opaque. It is very soluble in water. In close vessels it may be heated to redness without alteration, but by exposure to the air absorbs oxygen, and becomes cyanate of potassa—KO, Cy O. The purity of this cyanide is best ascertained by its property of dissolving the red oxide of mercury, twelve grains of the pure salt dissolving twenty of the finely-pulverized mercurial salt. The principal use of cyanide of potassium is in electro-plating and gilding, also in photography. Being similar and equally powerful in its action upon the animal economy with hydrocyanic acid, and as the dry salt may be preserved in a well-stopped bottle without change, it might be substituted with advantage for the latter in medicine, as the acid so readily undergoes decomposition.

Ferrocyanide and ferricyanide of potassium, termed also yellow and red prussiate of potassa, are respectively compounds of the metal potassium, with the salt radicals. *ferrocyanogen*—Fe Cy₃, and *ferricyanogen*—Fe₂ Cy₆. The preparation, manufacture on the large scale, properties, *et cetera*, of these salts have been fully discussed under the article IRON, Vol II., page 451 *et seq.*

SULPHOCYANIDE OF POTASSIUM.—This salt is a combination of potassium with the salt-radical sulphocyanogen Cy S₂ = Csy. It is present in the saliva of man and some other animals. It is prepared by heating the powdered anhydrous ferrocyanide of potassium with an equal weight of powdered sulphur in an iron pot. The mixture is kept in a fused state for half an hour, at a temperature above the melting point of sulphur, but below that at which bubbles of gas rise through the melted mass. The latter consists of a mixture of sulphocyanide of potassium and sulphocyanide of iron, with the excess of sulphur. This is treated with water, the insoluble matters removed by filtration, and to the colorless or slightly red filtrate, first heated to boiling, carbonate of potassa is added as long as a precipitate is produced. The liquid filtered

from this precipitate, on evaporation, yields crystals of sulphocyanide of potassium, from which any adhering carbonate of potassa may be removed by solution in alcohol.

Sulphocyanide of potassium— $K\ Cy\ S_2$ —crystallizes in long white striated prisms, which are anhydrous, and resemble nitrate of potassa in appearance and taste. They deliquesce in a moist atmosphere, and are very soluble in hot alcohol, from which the salt crystallizes on cooling. Sulphocyanide of potassium communicates a deep port-wine color to strong solutions of sesquioxide of iron, and is, consequently, much employed as a test for that metal in its higher state of oxidation. Nitric acid must not be present when testing for iron with this reagent. The Editor considers the sulphocyanide a very beautiful indication of the presence of iron. In the most dilute solutions a red coloring is at once apparent.

BITARTRATE OF POTASSA—Tartar—Argol—Cream of Tartar.—This salt is a constituent of many vegetables, and especially of the grape. The substance known as argol or crude tartar, consisting of bitartrate of potassa, tartrate of lime, and coloring matter, is found as a concretion upon the inside of wine casks, in which newly-made wine has been kept for some time. From this deposit the pure salt is obtained. The following is the process of purification pursued at Montpellier, as described by FIGUES:—The argol is boiled in water, and the solution allowed to cool; the crystalline deposit thus obtained is washed with cold water, and then redissolved in boiling water, to which is added pipe clay to the amount of five per cent. of the weight of the salt, together with a small proportion of animal charcoal. The addition of these substances promotes the separation of coloring matter. When the latter has completely subsided, the clear liquor is allowed to cool slowly, when crystals of the pure bitartrate separate. At Venice, the process of purification consists in the separation of the grosser impurities by repeated solution and recrystallization of the salt, after which white of egg and wood ashes are added to the boiling solution of the crystals, and during the effervescence which ensues the impurities rise to the surface and are skimmed off. According to DUFLOS, the crystals are most readily freed from lime by placing them in contact with dilute hydrochloric acid, and subsequently draining and washing them.

Bitartrate of potassa— $K\ O, 2\ \bar{T}$ —as usually met with, forms a white crystalline mass, having an acid and gritty taste. The crystals, which are irregular six-sided prisms, contain one equivalent of water, which is not given off at a heat much below the point at which the salt is decomposed. Water at 68° dissolves the one hundred and eighty-fourth part, and at 212° one-fifteenth of its weight. When heated, bitartrate of potassa swells up, evolves various volatile products, gives out an odor of caramel or burnt sugar, and a mixture of charcoal and carbonate of potassa, termed *black flux*, remains. Heated with an equal weight of nitrate of potassa, it leaves a residue of pure carbonate of potassa.

Powdered bitartrate of potassa, or cream of tartar, is frequently adulterated with various white mineral and organic powders. The proofs of its freedom from these

are complete solubility in water, and, according to the Edinburgh College, its decomposing power over nitrate of lead. The principal use of bitartrate of potassa is in dyeing, owing to its power of dissolving metallic oxides. It is used also in medicine.

Physiological Effects.—In small doses this salt has a refrigerant and diuretic action; in doses of half an ounce it forms a brisk yet gentle purgative. It is frequently used in admixture with sulphur as a mild laxative. In excessive doses it produces inflammation of the stomach and intestines.

Of other organic salts of potassa, none, with the exception of the oxalate and acetate of potassa, are used to any great extent in the arts or manufactures. These latter are prepared by saturating a solution of carbonate of potassa with the respective acid, and evaporating to the crystallizing point, or to dryness. Oxalate of potassa— $KO, C_2\ O_3 + HO$ —is used in the laboratory principally in the estimation of manganese ores. An acid oxalate—termed *salt of sorrel*, or *salt of lemons*—is employed to remove ink-stains and iron-moulds from linen. Acetate of potassa— $KO, C_4\ H_3\ O_3 \rightleftharpoons KO\ A$ —is chiefly employed in medicine.

ANALYSIS.—The salts of this metal are distinguished from all other substances by the following tests:—Sulphide of hydrogen, sulphide of ammonium, and alkaline carbonates, effect no change in their solutions. *Tartaric acid*, added in excess to a solution of a potassa salt, produces, especially after violent agitation, a white, crystalline, quickly-subsiding precipitate of bitartrate of potassa. *Perchloric acid* has a similar effect. *Fluosilicic acid* affords a transparent, gelatinous precipitate, which, when it subsides, is iridescent, and dries into a white powder. An alcoholic solution of *picric acid* throws down sparingly soluble yellow crystals of picrate of potassa. When heated on a platinum wire before the blowpipe, potassa salts communicate a characteristic violet or purple tinge to the flame. This reaction is obscured by salts of soda. By the test recommended by HARKORT, potassa salts may, however, be detected before the blowpipe when soda salts are also present. It depends upon the fact, that oxide of *nickel* when fused with borax in the blowpipe flame, gives a brown glass; and this glass, when melted with a potassa salt, becomes blue. Of all the tests for the detection of potassa salts, *bichloride of platinum* is, however, the most delicate. This reagent produces, in solutions of these salts, a yellow crystalline precipitate of bichloride of platinum and chloride of potassium— $Pt, Cl_2 + K\ Cl$. In applying this test, *the absence of salts of ammonia* must be previously ascertained, as these give rise to an analogous precipitation. A little hydrochloric acid is added collaterally with the bichloride of platinum, and if the precipitate does not appear after a short time, the mixture is evaporated to dryness at 212° ; and if potassa be present, on the addition of spirit of wine, the double chloride is left in the form of yellow shining crystals.

ESTIMATION.—In the determination of salts of potassa, they are almost invariably converted into the state of bichloride of platinum and chloride of potassium. The estimation is effected as follows:—The salt, first converted into chloride, is mixed with hydro-

chloric acid and bichloride of platinum in excess, and the mixture is evaporated to dryness at 212° . To the residue alcohol is added, and after standing some time, the whole is thrown upon a weighed filter, and the insoluble double salt of platinum and potassium is affused with spirit, until the washings leave no residue on evaporation. The salt is then dried and weighed. Every 243.5 grains of bichloride of platinum and chloride of potassium thus obtained, represent thirty-nine grains of potassium, or forty-seven of potassa.

It not unfrequently occurs in chemical investigations that a salt of potassa, and one of soda, exist collaterally, and it is desired to estimate the relative proportions of each. In such a case, the most convenient method is as follows:—The two bases are converted into sulphates by any available means, and weighed in this condition. After noting the weight, the mixed salts are redissolved in water, and treated with a solution of chloride of barium. The precipitate of sulphate of baryta thus obtained is collected by filtration, washed, dried, ignited, and weighed. From these data the respective quantities of soda and potassa may now be calculated; for, as one hundred parts of sulphate of potassa give one hundred and thirty-four of sulphate of baryta, and one hundred parts of sulphate of soda afford one hundred and sixty-four of sulphate of baryta, the larger quantity of the latter salt obtained than the ratio 134 : 100—is due to the salt of soda, and the proportion of the latter base present may easily be calculated, since one hundred parts of sulphate of soda represent 43.7 of soda. The proportion of potassa is then known by deducting the quantity of sulphate of soda found from the weight of the mixed sulphates. Every one hundred parts of sulphate of potassa remaining, represent fifty-four of potassa.

POTTERY.—*Potterie*, French; *steingut*, *porzella*, *töpfen*, German.—The earliest exponents of the potter's art supply indubitable, and, in some respects, unique data, for elucidating the theology, the literature, the manners and customs of the most remarkable nations of antiquity. Hence, from this cause alone, the history and practice of this art excite a deep and peculiar interest, irrespective of any other considerations to which its operations may give rise. These, however, are such as present their own special claim to notice, since the art itself, in its varied and comprehensive application, embodies the most complete and perfect medium for the exhibition of industrial skill. No branch of manufacture presents so ancient and intimate an alliance between art and utility as that of the potter. One of the most ancient and characteristic channels of national industry, the production of pottery takes its rise from a date which, in the Eastern hemisphere, is lost in the darkness of remote antiquity. The extreme plasticity of certain earths and their almost universal diffusion; the ease with which they can be fashioned into forms suited to ordinary domestic requirements; the consistency also which even natural heat will impart to them—have necessarily conduced to the general adoption of this class of manufactures, even in the primitive stages of savage life. The peculiar condition of plasticity, from the earliest ages, has rendered the potter's clay the most obvious material for the

gratification of that inherent desire to form or model the lineaments of some ideal image, or some palpable reality, which is a distinguishing characteristic of man's nature, and is patent as well in the infancy of society as in the early days of any individual. At what period the indulgence of a mixed mimetic and creative faculty was first applied to meet the requirements of primitive life, is a point of chronology that can never be exactly determined. As well might the Editor attempt to pen a diary of the reminiscences of his childhood, or chronicle the months and days when he drew figures on the sand, as seek to investigate and define the original invention and first production of pottery. BRONGNIART urges that when the antiquity of an art may be established by a train of simple reasoning and by the most natural deductions, one is not to evade admitting the fact through the fear of appearing to rest content with common and ordinary considerations. This observation is very happily applicable in the instance of pottery. Monuments, almost infinite in number and variety, the authenticity of which cannot be questioned, and so simple and clearly intelligible that no deep study is required to appreciate their interest and value—demonstrate that the potter's art, from primæval times, has been intimately associated with productions the most useful to man, as well as the most beautiful in themselves.

The ceramic art, both in its theory and its practice, unites a combination of qualities unknown in any other expression of human skill. No other industry presents so many divers considerations, all of them of the utmost interest, and each one rich in economic and scientific application. Finding its materials at the surface of the earth, pottery exhibits products the most simple and yet the most varied—the easiest to fabricate, but still, though fragile, of incomparable durability. Man, when in his weakest and most isolated condition, is able to extract clays for pottery from the ground beneath his feet; these materials, the spontaneous gift of nature, he fashions on the instant in accordance with his will; and, without either science or preparation, he even gives to them forms of a hardness sufficient to satisfy the first demands of social refinement. The products of these substances—so simple in their character, so abundant, so easy to bring together, so readily endowed also with every quality best calculated to facilitate their practical application—are absolutely endless in their variety, while, in their most successful exponents, their beauty may be pronounced matchless. Every species of form—from the classical severity of the early Greek period to the florid luxuriance of the wares of Saxony, France, and, one may now fairly add, England—here finds a fitting and worthy medium. Artistic excellence, both in the painter and the modeller, can here develop its highest capabilities. A material, which science teaches to present the most lustrous surface, which is solid, imperishable, and admirably qualified for the application of varied and brilliant colors, offers such inducements to the painter for the practice of his art, that the pencil of the glorious RAFFAELLE himself was occasionally employed in its decoration.

The potter's wheel, an implement identified with the

most important class of fictile productions, may have been the first piece of mechanism invented by the grandsons of NOAH, and originally employed while the earth was yet moist from the waters of the flood; or it may have been produced in various parts of the antediluvian world, long before the tremendous visitation of the deluge. Certainly the most ancient mechanical appliance that industrial art has adapted to its use, the potter's wheel is no less distinguished for its simplicity; and, at the same time, it exhibits so perfect a contrivance for imparting, under expert direction, beauty and utility to shapeless masses of matter, that it has descended from age to age to the operator of the present day without any important modification. Indeed, so absolutely identical is the mode of working, with reference both to the mechanical and the manipulatory processes now in use in this primitive branch of fictile art, with the system prevalent some thousands of years before the Christian era, that were it possible to resuscitate the mummy of an ancient Egyptian thrower, he might immediately find lucrative employment with the MINTONS, COPELANDS, CHAMBERLAINS, KERRS, and others, of the present day. According to Genesis, one is warranted in concluding that the potter's wheel was known to all the early families, and that it was retained and used by them when they had been dispersed abroad over the face of the earth.

In countries where the drying influences of the sun and air are pre-eminently powerful, the desiccation of clays after rain must necessarily have attracted attention. The plastic nature of these simple substances while in one condition, and their compact mass when in another, together with the ease with which in the former state they could be manipulated, and in the latter, fixed into form, cannot fail, at an early period, to have indicated their applicability to those useful purposes that provide for some of the most urgent requirements of human life. The want of vessels that would contain liquids, and also resist the action of fire, would naturally arouse the exercise of man's inventive powers. The hard shells of certain vegetal productions, such as gourds and the larger kinds of nuts, together with the skins of animals, might be easily transformed into recipients for fluids. The preparation of these materials, however, implies the possession of tools, together with a previous knowledge of some elementary manual arts. But then, such vessels being obtained, and the action of fire and its use in the preparation of food being understood, but little of real assistance could thus be acquired. Vessels of this description would scarcely be competent to render available the known services of fire. In such circumstances, some savage tribes have been constrained to adopt the expedient of dropping hot stones into the liquids in their frail vessels, in the hope of so imparting to them some degree of warmth—a dilatory and unsatisfactory process, and one that would be gratefully abandoned upon the discovery that certain earthen substances possessed the property of resistance to the action of fire.

Whether the fashioning and hardening of clay was first practised by the potter or the brickmaker, must ever remain a matter of speculation. Probably both uses

of the common material were discovered about the same period, and under the same circumstances. Bricks, *thoroughly burned*, it is known, were employed at the building of Babel, two thousand two hundred years before the Christian era. And, again, it is also certain that pottery, properly so called, had attained to an important condition of usefulness in very remote ages, since the earliest authentic records allude to the potter's wheel as an implement, even then, of high antiquity. In all parts of the habitable globe the same requirements would be felt; and as similar means for satisfying them would everywhere abound, men would naturally be prompted to the exercise of that kindred ingenuity, which had been implanted alike in them all as a universal heritage: and thus, amongst races rude and uncultivated, and in all other respects utterly ignorant of the arts that minister to human convenience, it has been satisfactorily traced that earthen vessels had been in use centuries before the existence of any such people was conjectured. Vases, for example, have been discovered amongst the aboriginal Indians on the Musquito shore, which by them were treasured as vestiges of antiquity; and there is every reason for believing that these fictile works were the production of the ancestors of the people amongst whom they were found, since the remains of ancient potteries exist far up the Black River in that region. PLATO describes the ceramic art as amongst the earliest on record. VITRUVIUS, again, affirms that in the Augustan age the Romans made their water-pipes of potters' clay; and after the Roman conquest potteries were established in England, where the fabrication of similar pipes for the same purpose was introduced. These pipes were about two inches in thickness, and firmly joined together with common mortar, mixed with oil; and, to prove both the durability of the material, and the tenacity of the compound, some relics that were dug up about a century ago in Hyde Park, London, were found to be in the most perfect condition, and as well suited for their use as when they were at first manufactured. A claim has been advanced on the part of the ancient Britons to a knowledge of the art of working pottery anterior to the Roman invasion; and the fact that cinerary urns of earthenware have been repeatedly exhumed from Celtic barrows in different parts of the kingdom, tends to warrant the assertion. Many writers are inclined to the opinion that the aboriginal Britons were indebted for these works to the Venetians. There appears no reason, however, for withholding from our Celtic forefathers the credit of having produced their own rude pottery, at a period antecedent to the earliest visit paid to their shores by adventurous and enterprising voyagers from lands lying nearer to the sun-rising. Remains of considerable Roman potteries are to be traced in various parts of England, and especially in Staffordshire, on the site of the great potteries of the present day.

There is something strangely suggestive in the relics of ancient pottery-kilns that still linger on the scene of their former active operations. The modern Staffordshire potter has derived no heritage from his Roman predecessor. There had been no continuity of work. Centuries of disuse had obliterated the very memory

of those remote artificers, and tradition had not even whispered of their scene of action. The potter established himself in Staffordshire, altogether unconscious of his vicinity to the spot in which long-buried laborers in his own handiwork had exercised their mutual calling. He saw that the natural materials suitable for his purpose were there abundant; and, having settled down, he plied his wheel, and threw his clay, and burned his pots—absolutely ignorant the while that he was reviving operations with which that district, in ages long past away, had been familiar. It was not until after many years of laborious occupation, that the upturned fragments of unwonted vessels casually revealed the ruins of an ancient furnace, and significantly declared that the potter's wheel was again revolving above the potter's tomb.

The antiquity and the nobility of the potter's art is demonstrated by repeated references to it in Holy Writ, and especially in similitudes which emanate directly from the Divine imagery. Indeed, from Proverbs, the twenty-sixth chapter and twenty-third verse, one would almost be led to suspect that the art of glazing earthenware vessels had been discovered seven hundred years before the Christian era. The words are, Burning lips and a wicked heart are like a potsherd covered with silver dross. Now it is a well-known fact that silver is generally refined by means of lead; the two metals usually occur together, and if lead be strongly heated in an earthen vessel a partial glaze is communicated to the surface, and this probably led to the discovery of a glaze.

Not only do the Scripture texts now alluded to establish for the operations to which they refer a very early date, but, what adds materially to the peculiar interest of the principal and most essential processes, they show that the mode of fabrication remains up to the present time substantially the same. By the ancients also the plastic art was employed for the highest and noblest purposes. Homage to the dead, and victory to the living, were typified in the votive products of the potter's skill. Eminence in the art was distinguished by public patronage, and chronicled by poets and historians. The profession of ceramic artists was held in high honor, and a college of potters was established at Numa eight centuries before the Christian era.

The term *Pottery*, which is derived from the Latin *Potorium*, the name given by the Romans to drinking vessels, does not convey any signification that denotes either form or substance.

The word *Ceramic*, the generic title by which works in this department of art-manufacture are now known, is derived from the Greek. The Greek word, however, differs from its Latin synonym, in the circumstance that it primarily signifies the *horn of an animal*; and it has obtained its secondary and generally recognized signification from the early use of horns for drinking vessels, as also from the more or less literal adoption of the form of drinking-horns in the plastic materials with which such vessels have been fabricated. Representations of genuine *drinking-horns*, the primitive *ceramic* vessels, are of frequent occurrence in illustrations of ancient festivals; and, though they appear

much varied in their constructive details, the original type is distinctly apparent in them all.

The addition of the heads of animals at the extremity of the horns seems to have been very popular; and numerous examples are extant in which the heads of the eagle, dog, and other creatures, appear thus cumstanced.

The name thus originally applied to drinking vessels alone, was next adopted by the potter in reference to such of his productions as were designed for somewhat similar uses, and in which the same forms were introduced; and then it was gradually extended in its application, until it comprehended the entire range of fictile manufacture.

Notwithstanding the fact that articles of domestic utility were the first to exercise the skill of the potter, but little is known of the forms and composition of these earliest vessels. Their fragility indeed, coupled with their trifling intrinsic value, would naturally render it improbable that more than a few occasional relics should survive the period of their original fabrication. Some few primitive specimens still extant, that from their character seem obviously to have been destined for household uses, BRONGNIART objects to recognize in that capacity, in consequence of the permeable nature of the clay of which they are composed. But it may be suggested that this eminent savant would scarcely have advanced such an opinion, had not the early practice of saturating these vessels with oil for the purpose of obviating their porosity escaped his observation. The lapse of centuries and long disuse would have caused the total evaporation of the counteracting medium; but that porous clay, by the application of oil, may be rendered impermeable by ordinary liquids, does not admit a doubt.

It would naturally have been most desirable that a ceramic museum, or an essay on ceramic manufactures, should commence with examples of the first pottery that ever was made. This the very nature of the fictile art has rendered impossible; and yet, though the actual objects may be wanting, their pictorial representation has been preserved in the varied decorations of other and later productions of the same class; and thus, through the agency of pottery when in a more advanced condition, the image and purpose of the earliest works of the potter have been preserved and handed down to modern times.

Like the first rise of nations, the first applications of art and the original productions of manufacture are for the most part mythic and fabulous. After a while, probable traditions arise; and then, as the stream of time flows steadily onwards, veritable history at length stands confessed with well-defined lineaments. Such is precisely the condition of the ceramic art. The very weakness of its primitive elements is such as to baffle the most penetrating research. Gradually some works appear impressed with the capacity of endurance. In due time the number of these clay-constructed conquerors of time increases, and they assume variously diversified forms. There succeeds but a brief interval, before the history of pottery supplies one of its most graphic chapters to the history of mankind.

BRICKS.—The sun-dried products of Egypt, Assyria,

and Chaldea, embodying the earliest existing illustrations of fictile manufacture in its simplest application, are the only examples of their era that have survived the ravages of time.

The *brick*, without doubt, was one of the primitive efforts of plastic labor. Its geometrical form would of necessity be suggested by the want of some constructive materials, with which buildings might be erected with a greater uniformity of surface and precision of outline than could be obtained by rough coatings of mud. When once adopted, the palpable utility of bricks would render their introduction universal, and their use permanent. The use of bricks, indeed, has continued with but slight modifications from the building of the Tower of Babel to the present day.

BIRCH, in his learned History of Ancient Pottery, displays much research in treating upon the historical value attached to these silent, yet eloquent witnesses of the past. He affirms that the bricks of Egypt not only afford testimony to the truth of Scripture as to their composition of straw and clay; but also that, by the hieroglyphics impressed upon them, they transmit the names of a series of kings, and thus testify to the existence and date of edifices, all knowledge of which, except for these relics, would have utterly perished.

The bricks of Assyria and Babylonia, in addition to similar information, by their cuneiform inscriptions denoting the localities of the buildings for which they were made, have determined the sites of ancient Mesopotamia with a precision and completeness that could have been obtained from no other sources.

The general form of all these bricks is rectangular, those presenting a curved outline being of very rare occurrence. In so arid an atmosphere as that of Egypt, a country in which rain seldom falls, sun-dried bricks would effectually resist the action of any moisture to which they might be exposed, and they would endure for ages. VYSE states that the pyramids of Dashour, Illahoon, Howara, Abú Roash—the walls of Sais—the fortresses at Samneh, Centra Pseleis—the walls also of the Memnonium at Thebes, and the great wall that inclosed Egypt on the Eastern side from Pelusium to Heliopolis, a distance of one thousand five hundred stadia, or furlongs, were constructed of these sun-dried bricks. And, in addition to these more important works, the same materials were in constant use for the erection of private tombs and other edifices. Sir GARDINER WILKINSON adds that this material was employed in the great wall built by Sesostris across Egypt—the Gisir-el-Agoos—and for a small temple at Ekmin.

The rich alluvial soil of both the Delta and the Fayoum, at a remote period of Egyptian history, must have determined that the brick-manufacture should be established in those districts. The mud and slime yearly deposited by the Nile were peculiarly adapted for pottery purposes. BIRCH states that an analysis proves about one-half of the substance of this deposit to consist of argillaceous earth, one-fourth being carbonate of lime, while the residue comprises oxide of iron, carbonate of magnesia, and water. Close to the river's banks the deposit is much mixed with sand, which it loses in proportion as it is carried by the water further from them, so that at a certain distance

it consists of pure argil or clay, which at the present day forms excellent bricks, tobacco-pipes, and stucco. Amongst the earliest bricks in existence, those may undoubtedly be reckoned which were made for the construction of the various brick-built pyramids, although it is not possible at present to determine the relative antiquity of all these edifices. Several of them, however, have been ascertained to be tombs of monarchs of the twelfth dynasty. Bricks of this class, formed of Nile-mud held together by chopped straw, continued to be manufactured in Egypt until about the tenth century before CHRIST.

The next step in the progress of the brick manufacture was the substitution of kiln-baked for sun-dried clay. An earthenware of a dull, coarse appearance, without any surface, polish, or glaze, was produced by this process; and it was employed for making sarcophagi, sepulchral cones, figures, vases, and other objects, in addition to the simpler bricks. All this baked pottery is *terra-cotta* in its simplest form. The external color is always some shade of red, though both the tint and the texture vary considerably in accordance with the degree of heat to which the pottery may have been exposed. A comparatively low temperature was sufficient for producing the soft pale tint, that appears to have been so generally preferred; in this condition, however, the *terra-cotta* is absorbent, though not sufficiently porous to allow water to escape. The absorbent property of this Egyptian *terra-cotta* is found to have been determined by the temperature of the furnace in which it was baked. The average size of the sun-dried bricks used by the ancient Egyptians was seventeen inches in length, eight inches in width, and in thickness five inches; those that were baked were generally somewhat smaller, and they appear to have been chiefly used in constructions that were exposed to a contact with water.

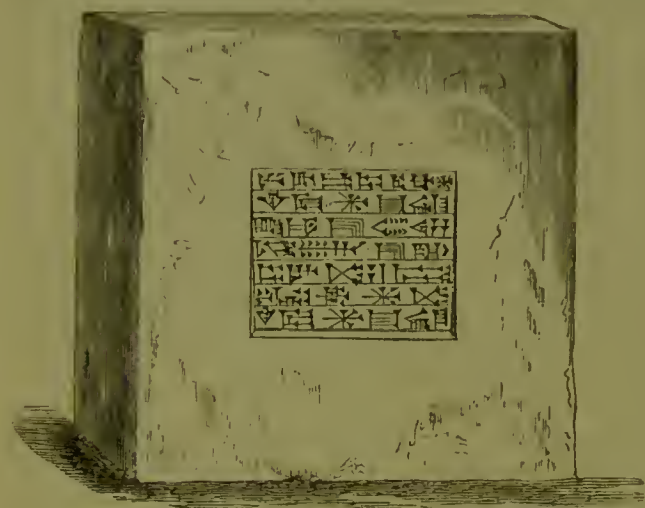
Both the Assyrians and the Babylonians used sun-dried bricks, as well as those that were baked in the furnace. The former were chiefly employed in the construction of the massive and lofty mounds upon which the more important edifices were constructed, the latter being substituted when more finished and careful brick-work was required. The kiln-baked bricks are generally of a pale-red hue, and they bear an inscription in the arrow-head character, which is impressed on the mass in true intaglio, and not obtained in a sunk bas-relief as in the Egyptian examples. In the Assyrian bricks the inscriptions cover one of the sides, or they sometimes run along the edge; but the Babylonian brick-makers stamped their inscriptions with moulds that covered only a comparatively small portion of the surface of each brick, somewhat after the Egyptian fashion. The inscription upon the specimen from Babylonia—Fig. 425—now preserved in the collection of the Royal Society of Literature, is read by Sir H. RAWLINSON as follows:—

(of) NEBUCHADNEZZAR,
the king of Babylon,
founder of Beth Digla, or Saggalu,
and of Beth Tzida,
son of NEBOPALASAR (I am).

Dr. HINCKS and Mr. LAYARD read *Beth Shaggah* in-

stead of *Beth Digla*. The rectangular bricks of Assyria vary in size from a square of twenty-two inches to one

Fig. 425.



of twelve inches, many of the varieties being elongated rectangles; their thickness also varies from four and a half to three inches. The Babylonian bricks are smaller, their maximum dimensions being a square of fourteen inches by four inches in thickness. Occasionally bricks of various shapes, and variously colored, are found throughout Mesopotamia.

The inscriptions that impart a peculiar value to the kiln-burnt bricks of Assyria consist of various formulæ, that have more or less direct reference to the edifice of which it was intended that they should form parts, together with the name, titles, and sometimes some steps in the genealogy of the reigning king. The formula upon each brick in a building was the same, with some unessential but very significant variations, such as the interchange of certain cuneiform equivalents. It is these variations, as BURCH observes, that teach the secret of the language. The inscription on the bricks of the N.W., or oldest palace of Nimrûd, which is in three lines, Sir H. RAWLINSON has read as follows:—

This is the palace of ASAR-ADEN PAL, powerful king, king of Assyria;

Son of ABED-BAR, king of Assyria;

Son of PUL, powerful king, king of Assyria.

By the Greeks sun-dried bricks were occasionally used for the construction of fortifications, since they were found to offer a more effectual resistance to the battering-ram than such as had been submitted to the action of the furnace. The walls of Mantinea afford a celebrated example. The same primitive and simple materials were also employed in the walls of the temples of the Lepræan Demeter in Africa, and of the Stirian Demeter at Styros, and in those of the shrine of Æsculapius at Panopeus. Kiln-baked bricks, however, formed very commonly the walls of their less important buildings amongst the Greeks; and, in some instances, they may have been introduced by them into their nobler edifices. But Greece was a land abounding in stone, and the Greeks preferred the natural building material of their country to the productions of the kiln. Greek bricks were named from their dimensions

measured in palms—*didōron*, of two palms, or six inches in breadth, the length being one foot; *tetradōron*, of four palms, a square of one foot; and *pentadōron*, of five palms, a square of fifteen inches. In addition to these, with the view both to render their works more solid, and to improve their appearance, the Greeks occasionally made use of bricks of half the foregoing dimensions. VITRUVIUS describes another Greek brick under the title of *lydron*, which was six palms in length and four in width—that is, eighteen inches by twelve inches.

Bricks were used in profuse abundance by the Romans, both in the imperial city itself and throughout the empire. It was the boast of AUGUSTUS, indeed, that he had found a brick-built Rome, but that he left it a city of stone; from the time of TRAJAN, however, the ancient system of brick construction again became prevalent, and was never subsequently discontinued. The Romans frequently used their bricks in layers, alternately with masonry of rough stones, and they also as commonly constructed edifices of every description entirely with bricks. The clay of the Roman brick is remarkable for its hardness, and it generally has a fine red color. The baked bricks were designated *cocti* or *coctiles*, and the various sizes in constant use were further distinguished by the terms *bipedales* and *æquipedales*, or two feet and eighteen inch bricks. Very minute particulars respecting the bricks of the Romans are given by both PLINY and VITRUVIUS, and the examples that are continually found in this country in considerable numbers fully corroborate the accuracy of their statements. The general sizes of the existing Roman bricks are seventeen by eleven inches, and fifteen by fourteen inches, the prevalent thickness being about two inches. Upon some of the earlier Roman bricks, the names of the consuls who were in office at the time of their fabrication may still be traced. The inscriptions stamped upon other specimens proved that the wealthy Romans of the imperial city derived no unimportant portions of their revenues from these, the simplest of fictile manufactures. The largest number of Roman bricks—or, possibly, of bricks that may have been made by Anglo-Saxon potters after the Roman fashion—that is now known to exist and to be in use in any one spot in England, may be seen forming parts of that most venerable and interesting edifice, the abbey church of St. Alban.

TILES.—In addition to the large bricks, whether sun-dried or furnace-baked, that were made for constructive uses of whatsoever kind, the ancients also manufactured vast quantities of thin tiles, of various sizes, and employed them for a multiplicity of useful purposes. Roofing-tiles were made much after the manner of similar appliances at the present time. Small flat tiles, and large ones also, were in habitual use for inlaying. Wall surfaces were variously decorated by this process, which was also applied to the adornment of door-jambs and other similar parts of buildings. Still smaller tiles, or tesserae, produced the inlaid or tessellated pavements that are so happily characteristic of ancient architecture. For all these purposes the tiles employed were formed in the East of a paste or body that would readily receive the glazing, with which in those regions their

surfaces were uniformly covered. The glazed tiles of the Egyptians, of which examples remain of a period as early as that of the sixth dynasty, were composed of a sandy friable compound, containing but little true clay, and exhibiting in different specimens considerable variety in the proportions and sometimes in the nature of its constituents, according to the manufactory or the period of production. This comparatively impracticable material was employed by the Egyptian potters because their silicious glaze—the use of lead in glazing not having yet been discovered—required to be applied to fabrics also silicious, and in which the sand was held in a granular condition—a result that was effected in the tile-body by the clay. The glaze itself, apparently formed of pulverized silica and soda, obtained its colors from the admixture of metallic oxides. An oxide of copper produced the well-known and deservedly famous Egyptian celestial-blue glaze that still retains its lustre untarnished, and will endure a comparison with the finest productions of modern science. The green glaze is of a kindred nature with the blue; and manganese, gold, silver, tin, and probably the suboxide of copper were the agents that produced the violet, yellow, white, and red hues. Of these colors, the blue is the one that is pre-eminently characteristic of the potters of Egypt.

The Assyrians applied a glaze or enamel to some of their kiln-dried bricks, on one face only, which was also enriched with various architectural devices, and so they provided themselves with substitutes for inlaying-tiles. The colors used by them were blue, yellow, white, red, and black. The specimens that remain are comparatively few in number, and in both their enamel and their hues they have lost much of their original effectiveness. That the Babylonians adopted a similar usage, is attested by the fragments of glazed ware that are scattered throughout the ruins of ancient Chaldea. By the Eastern nations of antiquity tiles of another class were in constant use for the reception of inscriptions, and in very many instances they were made to discharge the duties now assigned to writing-paper. The Assyrians were the great writers upon tiles, and they also employed cylinders and prisms for the same purpose. Documents of every conceivable variety were engraven on these singular but imperishable tablets, and the writing itself was executed with a minuteness, as well as a delicacy and precision, that are truly extraordinary. Many of these fictile records are of simple terra-cotta of the finest quality, while others are coated with a vitreous enamel. After the ancient national spirit of Egypt had in a great measure passed away with the departure of Egyptian independence, the papyrus often yielded on the banks of the Nile to terra-cotta, as the material for writing. Egyptian inscriptions on tiles, however, differ from the Assyrian in this important quality—that they were written in the ordinary black ink with a reed, and not incised with a sharp graving instrument before the tile was placed in the furnace.

Tiles were extensively used by the Greeks, both for roofing and for the flues of baths, and also in the construction of many of their tombs. The roofing-tiles are of large size, flat, and square, sometimes with flanges, and they have semicylindrical imbrices or rain-tiles to

cover their lines of junction. Two of the flat tiles in the British Museum measure two feet three inches, by eight inches. Many of these tiles are variously stamped with brief inscriptions in oblong labels. The imbrices are without inscriptions, but have painted ornaments. Another variety of Greek roofing-tiles were placed on the ends of the flat tiles for the purpose of additional security; these tiles, which are very ingeniously adapted for the duties required from them, are sometimes found to have been inscribed. The sepulchral tiles are of two kinds: those of the first variety are flat, and they were used to form a floor on which the remains of the deceased were placed; the other tiles are curved for the purpose of forming an arched covering. Drain-tiles, as well as those used for flues, were made by the Greeks of terra-cotta, and it is highly probable that they both employed the same material in the formation of the hollow floors of their own hypocausts, and transmitted that application of it to the Romans. The well-known *Keramieus*, as its name significantly declares, was a quarter of Athens almost exclusively devoted to the manufacture of bricks and tiles. Bricks and tiles were but rarely in use amongst the Etruscans; and the latter, when employed by that remarkable people, were apparently for the most part restricted to sepulchral purposes. Some late tiles of this class have been discovered, which are impressed with brief commemorative legends; and a single instance has been recorded of an Etruscan monumental tile, upon which the figure of the deceased had been incised, somewhat after a mediæval fashion, in addition to the customary inscription.

By the Romans tiles were used in great abundance, and they were adapted to various requirements. Roman tiles are found in much greater quantities than bricks, so much so, indeed, that it is by no means uncommon to apply the one term—Roman tiles—as well to the bricks as to the tiles themselves. The Latin equivalent for this word tile—*tegula*—is derived from the verb *tegere*—to cover—which expresses the primary application of Roman tiles. Thus ISIDORUS writes, *Tegula, quod ædes tegat*—a *tegula* or tile—because it covers houses; and he adds, *Imbrex, quod accipiat imbres*—an *imbrex*, or curved joint-tile—because it receives, that is, *wards off*, the showers. The tile-makers were distinguished by the title of *Tegularii*. Roman tiles closely resemble the bricks in their composition and mode of production, but their paste is generally somewhat inferior in quality, and the tile is always much thinner than the brick in proportion to its superficial extent. The flat *roofing tiles*, in common with those devoted to other uses, have inscriptions stamped upon them, their own special characteristic being their flanges. These flanged tiles were used for roofing both public and private edifices, for hypocausts, and for pavements, and numerous instances occur in which they appear banded into the Roman wall masonry. The flanges of two adjacent tiles, which generally rise two and a quarter inches above their flat faces, were covered by an *imbrex* set inverted over them, and by a repetition of this process the required roofing was completed. The end-tiles are found to have been suitably modified in form and adjusted to their office; the existing specimens are provided with spouts, and decorated either with the

brush or in relief. Some roofing-tiles, however, were made quite flat, and were hung, lozenge-wise, from one corner, overlapping one another like scales, or like feathers, as the Romans evidently preferred to draw the similitude, since they designated this style of tile-roof *peacock-work*, *opus pavoniacum*.

Flue-tiles, which are necessarily hollow, almost invariably measure sixteen and a half inches in length, by six and a half inches in width and five in depth. They have their surfaces scored either with wavy lines or more systematic patterns.

Drain-tiles, or terra-cotta pipes, are larger than those used for flues, and they were formed in a manner consistent with their object.

Wall-tiles, employed by the Romans for casing interior wall surfaces, are large thin squares of terra-cotta, and they generally were decorated on one side with incised figures and patterns.

The small paving-tiles, so well known as *tesserae* and *tessellæ*—the latter term a diminutive of the former—the components of *tessellated pavements*, declare their square form under their title, which is evidently derived from the Greek *τεσσαρες*—*tessares*—*four*. They were made by cutting larger tiles into small cubes, or else they were formed in the first instance in distinct moulds. They vary in size from about an inch to a quarter of an inch square. The red portions of the mosaic work of pavements were produced by these small terra-cotta cubes, which were also used, though less frequently, in the formation of Roman mosaics for other purposes. It may be observed, that of the Roman tessellated pavements now known to be in existence none are earlier than the Augustan age, while the greater number date from the succeeding century.

There remains to be noticed one other distinctive application of their large flat tiles by the Romans, which is their use of them both in the formation of their graves and for preserving their commemorative monumental inscriptions. In close conformity with the Greek usage, some tiles laid flat formed the flooring upon which the body might rest, and others set sloping in opposite directions provided a simple ridged covering to protect it from the superincumbent earth. The vases that contain burnt bones are sometimes found to have been protected in a similar manner. The inscribed tiles, having their Greek or Latin legend generally written across them from side to side, were placed very much in the same manner as modern gravestones.

The inscriptions that are preserved upon the various tiles that have come down from the Roman times, abound in highly interesting as well as very valuable information. Considerable numbers are inscribed with the names or initials of the consuls of the year when particular specimens were manufactured. Still larger numbers set forth the names of the potteries and of the estates, with their proprietors, from which the clay was procured and where the tiles were made, together with notices of the manufacturers, and various brief descriptive or auspicious sentences and mottoes. The consular tiles, as they may be distinguished, are found only in Italy; they appear to have been thus stamped, in conformity with some law of about the time of TRAJAN, as a guarantee of the quality of the

clay used in the fabrication of them. Large collections of these tiles, obtained from almost every great edifice of ancient Rome, are still in existence, and many are yet in use upon the roofs of the churches of the modern city. The tile-inscription, whatever its character, was produced from a stamp or die in a low sunk relief, the raised letter being on a level with the face of the tile itself. In the centre of the circular composition upon a tile now in the British Museum, is a small medallion formed of a figure of victory, which was the mark of the potter; this is encircled by two bands of letters; those of the outer band are larger than the others, and with them the inscription commences. It may be read thus:—*OPUS DOL (IARE) DE FIGUL (INIS) PUBLIANIANIS (EX) PREDI AEMILIAES SEVERAES*—*Pottery from the Publian potteries, from the estate of Æmilia Severa*. This, though a characteristic, is by no means a perfect specimen of these remarkable inscriptions. As a matter of course, in other specimens, the productions of different establishments and various makers, the central devices exhibit a variety of characters; they are not very numerous, however, and sometimes they are altogether omitted. The most complete stamps, says BIRCH, have the date of the emperor or of the consulship, the name of the estate which supplied the clay, that of the pottery which baked it, and of the potter who prepared it, sometimes even of the slave who moulded the tile, and the very dimensions of the tile itself. In a few instances also the tiles have inscriptions, indicating the places where they were to be used. The greater number of these appear to have been directly associated with the Roman soldiery, by whom in many instances they were made, and in whose quarters, camps, and places of interment they were applied to their destined uses. These relics have served to trace out the stations of various legions, and even their line of march from station to station. In some instances the tiles specify, not a particular legion only, but certain cohorts of those legions. The numbers and the titles of the legions are given in these singularly interesting inscriptions, as *the Second, August; the Sixth, Victorious, Pious, and Fortunate*. The letters are always sharply expressed, as if from well cut metallic dies, and they are more generally arranged in the form of a foot than of a circle. The route of the twenty-second legion has been traced through Germany by the tiles that lingered at its successive stations; and in this country these tiles have declared what legions they were that occupied quarters at places most distinguished in Roman Britain. Thus the tiles of the sixth and ninth legions have been found at York; those of the twentieth, Valerian and Victorians, at Chester; and others of the second, at the ancient Isea Silurum, or Caerleon.

CHINESE CERAMIC MANUFACTURES.—It is not known whether there have been preserved amongst the Chinese any specimens either of terra-cotta or of glazed pottery of a date earlier than the great tower of Naukin, which was completed in 1431, after nineteen years' work; several similar edifices having been successively erected and destroyed upon the same site. It consists of nine stories in height, and is constructed

entirely of glazed tiles and slabs of earthenware. At the present day the manufacture of common pottery is carried on to a great extent in China. Some vessels of this class, of very large size, are employed by wealthy Chinese as reservoirs for gold fish and aquatic plants, or for containing and storing up fruits and grain, and for other like purposes; but the smaller productions of the terra-cotta potteries of China, which are greatly encouraged by the government, are almost exclusively devoted to providing for the requirements of the humbler classes of the vast population. As an article of export, the common opaque pottery of China has been completely set aside by the beautiful and universally admired ware, distinguished by the title of PORCELAIN, which is formed from a fine and hard paste, possessing the peculiar quality of being *translucid*. Thus porcelain occupies a position midway between pottery and glass. It is presumed to be of Chinese origin, and it certainly was known and extensively manufactured in China from a very early period. The Chinese, indeed, claim for their ceramic manufactures the same far-extending antiquity that they assign to the history of their extraordinary empire. The isolation, however, which it has been the policy of the natives of China to maintain during so many ages, coupled with the guarded secrecy that so generally has enveloped their manufacturing processes until very recently, has precluded the possibility of national intercourse, and rendered hopeless the attainment of any credible and satisfactory information relative to the rise and progress of a particular industry in that country.

The first European who is recorded to have penetrated into China, and to have explored Chinese productions on their own soil, was the Venetian, MARCO POLO. Writing in the thirteenth century, this famous traveller alludes to the extent and importance of the porcelain manufactures in the Celestial Empire, and he states of one place, Kinsai, that there was nothing further to be observed, than that cups or bowls and dishes of porcelain wares were there manufactured. MARCO POLO returned to Venice in the year 1295, and died there in 1323. It seems to be highly probable that Chinese porcelain had been exported in considerable quantities to other Eastern countries, many centuries before it was seen in China by MARCO POLO. Thus mention is made of a service consisting of forty pieces having been sent in 1171 to NOUREDIN, the caliph of Syria, by his lieutenant, SALADIN, who afterwards became the hero of the crusades. This present may be considered to have travelled by way of Egypt, into which country and into Persia there can be no doubt of porcelain having been introduced direct from China, at a very early period, as an article of commerce. In 1474 the Venetian ambassador at the court of Persia considered it to be his duty to submit to his government a special communication upon the subject of this art-manufacture. Fifteen years later, amongst other rare and costly presents, an ambassador from the soldan of Egypt brought to LORENZO DI MEDICI some large vases of Chinese porcelain—*vassi grandi di porcellana*. Early in the following century the Portuguese, who were the first adventurers that doubled the Cape, imported the finest wares of the East, in large

quantities, into Europe, and from that period the different European nations gradually became familiarized with porcelain. CAVENDISH, the celebrated traveller in the time of Queen ELIZABETH, is generally supposed to have presented to his royal mistress the first pieces of oriental porcelain that came into England; but it has been also considered, that a few specimens of this precious ware had found their way to these shores as early as the commencement of the sixteenth century. Archbishop WAREHAM's silver-mounted bowl of the pale green thick porcelain, preserved at New College, Oxford, is one of the earliest specimens known now to be in existence in this country. In the year 1600 the English East India Company was formed, but it did not succeed in establishing a regular importation of *china* until after it had been for thirty years in operation.

From the earliest period the Chinese have systematically refused to export the finest, richest, and most valuable of their porcelain, except in very rare instances. It has also been their uniform practice to keep the composition of this manufacture a profound secret; and accordingly they have always endeavored to mislead all inquiring strangers, with the most marvellous tales respecting the nature and the preparation of the materials. Thus MARCO POLO has recorded that the Chinese collect a certain kind of earth, as it were, from a mine, and laying it in a great heap, suffer it to be exposed to the wind, rain, and sun for thirty or forty years, during which time it is never disturbed. By this means it becomes refined and fit for being wrought into the vessels above mentioned. Such colors as may be thought proper are then laid on, and the ware is afterwards baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect it for their children and grandchildren.

Other early writers have stated that the porcelain-composition is formed from marine shells, egg shells, gypsum, and other strange substances, which are tempered and thickened, in order to their being adapted to their future application, by being buried in the earth for eighty or one hundred years. Hence Dr. JOHNSON's fanciful derivation of the term porcelain itself—*pour cent années*. Lord BACON entertained the idea that there were strata or beds of the porcelain-clays in China which, being buried beneath the surface of the ground, by length of time became congealed and glazed into that fine substance which afterwards produced the China wares. At length some light was thrown upon the subject by the French Jesuit missionary, D'ENTRECOLLES, who learned many particulars respecting the production of porcelain, both from his converts and from Chinese books upon the subject, and was permitted in person to witness the actual processes of the manufacture. He fully detailed all the particulars in a letter, dated Jao-tcheon, September 1, 1712, which, together with specimens of the two principal materials, he transmitted to Paris. These specimens formed the basis of a series of experiments by RÉAUMUR that ultimately led, when the proper materials had been discovered in France, to the production of the fine porcelain of Sévres.

The high antiquity of the art of making porcelain, and the perfection to which it had attained amongst the Chinese long before any specimens had reached Europe, had for many years been well-authenticated facts, before any definite and precise information had been obtained from records preserved amongst the Chinese themselves. This equally valuable and interesting source of information was reserved for M. STANISLAUS JULIEN, the eminent Chinese scholar, to lay open before us in his translation of a work upon the history of the porcelain of King-te-Tchin, published by him at Paris in 1856, with an elaborate preface and notes obtained from the writings of various Chinese authors. Having referred to the remarkable circumstance, that the Chinese possess an exact chronology from the most remote antiquity to the present time, M. JULIEN states that their official annals record the Emperor HOANG-TI to have been the inventor of pottery, two thousand seven hundred years before the Christian era. Porcelain, the same chroniclers declare to have been first fabricated under the HAN dynasty, who flourished about 185 before CHRIST, thus claiming for the discovery of porcelain an antiquity approaching to two thousand years, and a priority of at least one thousand six hundred years over the first manufacture of this ware in Europe. After sketching out the progressive development of the porcelain manufacture under different dynasties, M. JULIEN proceeds to enumerate fifty-six establishments for its production; after which he describes minutely the great manufactory of King-te-Tchin, that for more than eight centuries has enjoyed the especial patronage of the Chinese emperors. Three thousand furnaces are now in constant operation at King-te-Tchin, which may be said to send their productions to the whole world. Their works may be grouped in two great classes—the one consisting of imitations of the ancient porcelains of the empire, and the other comprising new varieties of both form and color. Amongst the porcelains held in the highest esteem in China, as well as by Europeans, and which were made at early periods, are the celebrated *crackle* vases that are covered with a minute and delicate network of fine surface cracks, produced during the process of manufacture by plunging the heated porcelain in cold water, or by mixing stearite with the glaze. The cracks having been filled up with some thick, colored composition, or with a flux that has been tinctured ruby-red by dissolved gold, the porcelain receives its finish. The *egg-shell* is another early porcelain in the highest repute. Its texture is so slight and delicate as to be almost transparent, and yet jars and vases of considerable size were made of it, as well as cups, plates, and other smaller objects. It attained to its highest perfection during the second half of the fifteenth century of this era, when it was fabricated as thin as *bamboo paper*. Some of the finest examples of this porcelain are of a pure white; in others the glaze is creamy, and minutely granulated; and many others are painted chiefly with a cobalt-blue of exquisite beauty. The true cobalt became exhausted in China about 1500, when foreign cobalt was for the first time introduced into the Chinese ceramic manufactories. A native pigment,

found in abundance in all the provinces of the empire, and which is presumed to be a cobaltiferous manganese, is still used by the Chinese artists, who now obtain their true cobalt from England.

Not the least remarkable portions of M. JULIEN'S work are those which describe the practice of making, at King-te-tchin, an inferior species of porcelain for the express purpose of exportation, and which also direct attention to the fraudulent and deceptive practices of Chinese porcelain dealers in their transactions with foreign purchasers. Such impositions have not restricted their sphere of action even to the wide limits of the Chinese empire; nor are the inexperienced and unwary the only persons who have by these means been misled. In his highly interesting and most valuable work, *On the Manners and Customs of the Ancient Egyptians*, Sir GARDINER WILKINSON states that great curiosity and surprise were excited by the discovery in certain of the most ancient tombs at Thebes of small bottles of porcelain, unquestionably of Chinese manufacture, and bearing inscriptions in that language. These bottles are about two inches in height; one side of them is ornamented with a flower, and the other bears the legend. They are formed, not of very fine porcelain, but of such as might have been produced before the processes of the manufacture had attained to an advanced degree of perfection—a circumstance that was considered to corroborate their supposed production at a Pharaonic period, no less remote than that of the eighteenth dynasty—before CHRIST 1375 1289—in a tomb of which era one of the specimens was found by ROSELLINI. Subsequent investigations have proved that the characters of the writing upon these bottles were not introduced into China until about 40 before CHRIST, and also that the verses inscribed upon two of their number are to be found in the works of Chinese writers of the eighth century of this age. Similar bottles have since been purchased in China, where they are commonly used to contain snuff, medicines, and other articles of which small quantities only are required. These modern bottles have precisely the same inscriptions with those of the Theban tombs. Another of these bottles has been obtained at Khorsabad, and at Candy they have been seen exposed for sale in a large basket. Hence it is evident that they are exported at the present time from China, and would easily reach the Arabs of modern Egypt, by whom they were, in all probability, placed in the tombs for the deliberate purpose of deception. Such are the evidences that archaeologists of this day adduce, before they accept the authenticity of a startling discovery; and, in this particular instance, it is in consequence of these results of careful inquiries that the learned writer upon Egyptian antiquities, who first noticed the little Chinese bottles, is quite prepared to abandon all notion of their antiquity. It has been suggested by MARRYAT that the small seals of pure white Chinese porcelain, highly vitrified, that have been dug up both in Cornwall and Ireland, may, in like manner, have been purposely deposited to try the assumed credulity of archaeologists. These seals are all alike in form and size; the handle is formed of the figure of a monkey sitting upon an exact cube rather more than half an inch

square, and on the bottom of this cube is engraved the motto of the seal. It does not appear that such seals are now made in China, though it is quite possible that they may yet be discovered there in abundance. However they may have found their way, either to Cornwall or to the depths of an Irish bog, this one thing is certain—that, by some means, there they have been seen.

While the history of the porcelain manufactures of China to a certain extent has been laid open through the intelligent perseverance of M. JULIEN, all reference to the primitive operations of the Chinese ceramists still continues to be raised but little above

conjecture and speculation. When seeking to trace the progressive outline of the history of the ceramic art, it, accordingly, becomes necessary to have recourse to the accredited traditions of Egypt, Assyria, and Greece.

EGYPTIAN POTTERY.—The memory of the earliest miscellaneous pottery of Egypt has been preserved through the instrumentality of hieroglyphics, which commenced from the remote era of the third and fourth dynasties, before CHRIST 3000-2000, and represent various kinds of fictile vessels, the earliest of a red earthenware, in use for the ordinary purposes of domestic life. A succession of these curious sepulchral pictures enables

Fig. 428.



Fig. 427.



Fig. 426.



one to trace the progress of the potter's art amongst the ancient Egyptians, and its practice also, from the almost primæval period of the third dynasty, until the power of Rome had extended its influence along the valley of the Nile. Vessels of every variety of form, size, and application are thus represented; and by the same means mankind is rendered familiar with the simple manufacturing processes prevalent amongst the potters

of Egypt. In the tombs that the living Egyptians prepared with such sedulous care for their own final rest, and which they delighted to fill with graphic pictures of Egyptian life, the clay is seen in the act of preparation, and the artificers at work upon it; and close at hand are the furnaces in which their productions were to be baked. The wall-paintings of the tombs excavated at Beni-Hassan while the sovereigns

Fig. 429.



Fig. 430.



of the twelfth dynasty were in power, have supplied illustrative examples—Figs. 426, 427, 428, 429, and 430. After the clay had been dug up, it was prepared by kneading with the feet—a process denominated *hi hat*—Fig. 426. The clay in this state was divided into suitable masses by the workmen—Fig. 427—and carried by them—Fig. 428—to be wrought on the wheel or by the lathe. The wheel is represented twice in Fig. 429; it was a flat table, circular or hexagonal in form, and it appears to have been turned with the left hand, whilst the right was engaged in forming the

required vessel. The various objects, when formed, were placed in a blast furnace, cylindrical in shape, from the head of which the flames issued forth—Fig. 430.

With the advance of civilization, the potters of Egypt very considerably extended the range of their operations, and introduced into their various productions many important improvements. Egyptian pottery, however, does not appear at any time or under any circumstances to have aimed at a high art-character. It was a manufacture designed for purposes of practical utility, and its decorations were held to be altogether

subordinate to its usefulness. At the same time, the Egyptian potters were by no means destitute of some sense of the beautiful, both in form and in adornment, though in their most perfect works they fall far short of the artistic excellence generally prevalent in the fictile productions of the Greeks. True Egyptian vases may be said to be distinguished by the absence of a high mechanical finish, by the prevalence of forms which are evidently imitations of well-known fruits and flowers, by their pointed bases, and by the extreme smallness of their necks and orifices. There are also certain peculiar national conventionalisms of style and treatment, that impart a peculiar Egyptian character to the pottery of Egypt so long as the country itself maintained its own independence. Subsequently, after the substitution of Greek and Roman power for that of Egypt herself, the pottery of the Egyptians in many respects became assimilated with the cognate productions of Greco and Rome. It must be added that the more artistic of the ceramic works of the Egyptians exist in comparatively small numbers, while in the greater proportion of them the simplicity of their character scarcely rises above rudeness. The most important feature in early Egyptian pottery consists in their hieroglyphic legends, which very greatly enhance the value of the relics themselves, since they enable students to determine the age of specimens that are identical, both in their composition and in their type and ornaments, and to assign them their proper places in the history of Egyptian art.

In addition to their bricks, the Egyptians manufactured various objects in clay, which they considered capable of receiving a sufficient degree of hardness from the action of the sun. The perishable nature of such wares has not permitted many objects of this class to remain. The few that have been preserved are of a late date, and they almost exclusively consist of the small figures so commonly used in Egypt as votive offerings, together with various decorations for the interior of tombs. These relics were evidently fabricated in imitation of more valuable and costly works, for which they may have been originally substituted; or they may, in the first instance, have been designed to provide for the requirements of such as could not obtain fictile productions of a higher order.

The earliest and simplest pottery that the Egyptians placed in the furnace to be baked by an artificial heat, was formed from the ordinary unctuous and plastic clay which is regularly deposited by the inundations of the Nile. The earthenware thus produced is coarse and porous, without polish, and of a dull dark-red color, externally tinged with a purple hue, or inclining to a reddish-yellow when the action of the fire had been but comparatively successful. Improvements were gradually introduced into the paste of their terra-cotta by the Egyptian potters; and their manufacturing processes also, in course of time, underwent such modifications as enabled them successfully to undertake the production of an almost infinite variety of objects. The great majority of these works may be included under the comprehensive title of *Vases*—vessels varying in dimensions from being several feet in height, to being scarcely a single inch, and of corresponding circum-

ferences; and adapted, in their diversified forms, to the special requirements of every imaginable use. Those destined to contain liquids are of a jar shape. The Nile water, intended for oblations, was placed in others that are tall and thin, with a spout. Bread, roast meats, and water fowl were placed, says BIRCH, in deep dishes. Oils and drugs were kept in tall conical jars, carefully covered and tied down—ointments, salves, and extracts, in small pots. Other cosmetics were held in a jug with a spout; wine, honey, and other liquids were deposited in open-mouthed jars, out of which they could readily be drawn. Almost every purpose to which jars and other vessels of pottery, together with baskets and vessels formed of the common metals, are put in this country, was discharged by some species of terra-cotta vases, in the case of the ancient Egyptians. In vases of different kinds water was raised from the Nile and distributed by the water-carriers, and conveyed to the lips of both men and animals. Other vases were used in making and storing wine, in bringing it out for use, and in drinking it. The butcher, the poulterer, and the cook, had each their own vases, in which they disposed of their viands. Even the weaver used terra-cotta vessels to hold his flax, and reeled it out of them. Jars held the colors of the artist, and the cements of the plasterer. The grains of corn, before they were pounded in the mortar, and the flour after it had been thus produced, were kept in vases. Vases held the embalmer's bitumen, and the water used by the scribes. Vases also provided the hod of the laborer, the smelter's bucket and crucible, the jar of the cow-doctor, and the pail of the milk-man.

The pots which contained and preserved the mummies of the sacred ibis at Memphis were formed of a coarse red pottery, or, in some instances, of a finer glazed ware. Similar vessels were also used as receptacles for the mummies of certain sacred animals. Sepulchral vases of various forms were employed in their interments, by the humbler Egyptians, for receiving the intestines, after they had been removed from the bodies and had been embalmed. The *shabti*, or sepulchral figures, which were deposited with the mummies, and formed a part of the funeral relics, were made of terra-cotta, and, in some few instances, of sun-dried clay. The models of coffins or mummy cases, which HERODOTUS records to have been shown by the Egyptian undertakers to the relatives of the deceased, were produced in terra-cotta. The sepulchral cones, again, that were introduced for the purpose of decoration into the interior of the Egyptian sepulchres, were of the same material. These singular objects, that have excited so much curiosity, and caused such diversified speculations, vary from six to twelve inches in length, and are about three inches in diameter at their base. They bear stamped inscriptions, always of a funereal character, and, in almost every instance, stating the name of the person to be commemorated, and conveying some personal information respecting him. Figures and scenes, also, of a sepulchral import, are occasionally introduced instead of inscriptions. The inscriptions upon these cones contribute, in no slight degree, to elucidate the interior organization of

ancient Egypt, and to illustrate its political and social condition, by setting forth a long list of public functionaries with their relative degrees of precedence. As the eye ranges over these tickets of the dead, remarks BIRCH, one is forcibly reminded of the visiting cards of the living. Sacred scribes, royal officers and secretaries, clerks and accountants, priests, viceroys, counsellors, seal-bearers, scribes of the treasury and of the granaries, chamberlains, prefects, incense-bearers—all of them tenants of the sepulchres of the ancient No-ammou or Diospolis, and of still more ancient Noph or Memphis, seem to have left these relics behind them as if to make a call on posterity. Recent discoveries at Warka in Babylonia have proved that these cones were used as bricks, in the formation of the interior walls of the sepulchres, where they were arranged in patterns, their inscribed bases being outwards.

In addition to their varieties of form and size, the vases of the Egyptians may be distinguished by their having either two or more handles, or a single handle, or by their being altogether unprovided with any such appendage. The British Museum contains many highly interesting specimens of each class. The similarity that is so evident between these vases and the painted representations of them that frequently occur in the hieroglyphics, corroborates, in the most satisfactory manner, the descriptive fidelity, and consequently the historical truthfulness of the Egyptian picture-writings. This pottery of Egypt also most clearly indicates that, while it retains certain qualities peculiar to itself, it is the evident prototype of the more beautiful ceramic productions of the Greeks.

Amongst the objects made from baked clay in Egypt during the era of the Roman dominion, are lamps that bear a close resemblance to the terra-cotta lamps of Roman Italy; they take but a low rank, however, as works of art. Lamps of early date, and of higher artistic qualities, have not been preserved in Egypt.

Polished Egyptian Pottery.—The smaller and finer productions of the Egyptian potters, and such as were destined for uses immediately connected with the refinements of life, were either polished by a mechanical process, or covered with a vitreous glaze, so thin as to escape detection. Different clays were employed in the production of the polished vessels that were adapted to various uses; a distinct and beautiful variety is of a uniformly rich red color throughout, which was evidently held in high esteem by the Egyptians themselves. Many of the existing specimens are elegant in their design, and modelled with much skill. This ware, however, notwithstanding its merit, is inferior to the red pottery of the Romans; at the same time, it undoubtedly possesses the required property of cooling liquids poured into it. According to BRONGNIART, the analysis of the polished red ware is—

	Centesimally.
Silica,	56.13
Alumina,	18.54
Oxide of iron and manganese,	9.00
Carbonate of lime,	5.24
Manganese,	1.07
Water,	5.56
Carbonic acid,	4.46
	100.00

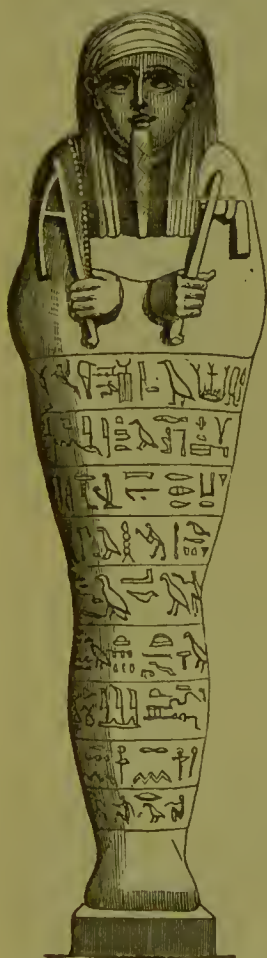
Some vessels of this ware have been found in the tombs at Thebes. Other varieties are formed from a brown or a black paste—in the others again, the paste is of a light-red tint. A white chalk coating generally covers the vessels and other objects of these classes, which may be considered generally to have been made in imitation of similar objects in more precious materials. Amongst the more characteristic specimens of this polished ware that remain, are small cruses or *lecythi*, for containing liquids, of which small quantities only were required. Some of these *lecythi* are double, and have their globular bodies and tall necks united by a narrow band of the terra-cotta. Other examples have oval bodies, narrow necks, and pointed bases; another kind of jug has a compressed body and wide open mouth, and sometimes it appears with two handles; again, other vessels are egg-shaped, while in some human and animal forms are introduced.

To this same class of polished pottery belong the vases that were made in Egypt after the subjugation of the country by ALEXANDER the Great, and which have been distinguished by the title of Græco-Egyptian. The texture of this pottery is comparatively fine and homogeneous, though, in some examples, it is very coarse and mixed up with white or grey particles of a stony nature. In color, different specimens vary from a deep to a pale tint of red or grey. Vases of various forms, and large bowl-like jars, are the principal works of this class that have been found; and they are adorned with figures, flowers, architectural devices and patterns, that are painted in black or red upon the clay.

Glazed Egyptian Pottery.—The substance already described as having been used in the production of their highly glazed tiles, was also commonly employed by the Egyptians for fabricating a vast number of other objects, all of them peculiarly characteristic of their makers. To this glazed pottery of Egypt the term *Porcelain* has very generally been applied: but this use of the word is altogether incorrect, since the glazed fictile works of the Egyptians possess neither the hardness, the compactness, nor the translucence of that peculiar class of ceramic productions. The nature of the material that, in this glazed pottery, was substituted for potter's clay, also distinguishes it from what might be appropriately styled glazed terra-cotta. The constituent parts of this pottery have been found to consist of silica, alumina, carbonate of lime, magnesia, and water; but it does not appear that these substances were combined in any definite or fixed proportions. Whatever amount of clay was incorporated with the compound, was evidently employed for the purpose of holding together the arenaceous portions of the mass; and on the other hand, the presence of the sand was necessary in order to secure the adhesion of the silicious glaze or enamel, which, with its coloring obtained from metallic oxides, was to cover the surface of every object. This peculiar and very beautiful ware was both extensively used in Egypt, and also considered to be of sufficient value to be imported into foreign countries; as is proved by the circumstance, that objects formed of it have been discovered in Greece and Italy. In Egypt this ware was manufactured as early as the sixth dynasty.

The vases made of glazed pottery are of small size, few of them being more than twelve inches in height; and such vases as were produced in this manner, were evidently designed rather for decorative than for useful purposes. They vary in form and in their style of adornment, many of them being evidently modelled in imitation of similar productions in the precious metals. Examples have been observed that are inlaid with a compound of a different color from the body of the vase. Inscriptions occur amongst the devices and patterns introduced into these works by the Egyptian potters; and it is worthy of particular notice that an Assyrian style of art is apparent in some specimens of the glazed

Fig. 431.



pottery, themselves undoubtedly of Egyptian production, that have been discovered amongst the relics of ancient Egypt.

In addition to the *shabti* or *shabshab* of terra-cotta, the same kind of sepulchral figures were made in great abundance in Egypt, of the brightly-colored glazed pottery. So numerous, indeed, are these singular relics, that the production of them must have constituted a staple manufacture in the potteries of ancient Egypt. Known to have been used only in Egypt, where they were universally employed by persons of all ranks in their burial ceremonies, the *shabti*—Fig. 431—which vary in height from about a single inch to about nine or ten inches, may be supposed to represent, and to have been substituted for, the human victims that at one time were sacrificed at the funerals of the great and wealthy. It appears from the formula inscribed upon the *shabti* themselves,

that the use of these figures was to aid the deceased in his labors of preparing and irrigating the ground, and raising the crop in the mystical fields of the *Aaheura*, or *Aahlu*, probably the bean-fields of the Egyptian Elysium, and in the transport of the food from the west to the east.—*Birch*.

In addition to this formula from the sixth chapter of the Great Ritual of the Egyptians, the inscriptions upon the *shabti* generally set forth in hieroglyphics the name, style, and titles of the deceased; and they are arranged in horizontal lines down the front of the figure, and in perpendicular ones upon its back. Some of the figures are found to have been executed with the utmost care, and with no common skill. The inscriptions are either incised or produced in intaglio from a stamp, or sometimes they are merely written upon the surface of the glazed ware. Examples have been noticed which had been made ready for sale, having the formula inscribed

upon them, and with blanks left to be filled up with such names and titles as might be required. The *shabti* are generally repetitions of the same type, which represents the deceased as swathed in bandages, after the manner of a mummy set upright, the head and hands alone being exposed to the view. The head has a peculiar covering, with pendent ends. From the chin depends the beard, apparently inclosed in a beard-case; in the right hand is a pickaxe, while the left hand holds a hoe and a cord, to which, and hanging over the shoulder, there is attached a basket containing the seed-corn. The figure stands on a plinth, and sometimes at the back there is a small slab for the purpose, as it would seem, of attaching it to the wall of the tomb. At the era of the eighteenth and nineteenth dynasties, *shabti* of a different and rarer type prevailed. They represented the deceased as standing, and habited in the costume of the period. The prevalent color is the bright Egyptian celestial-blue; but some *shabti* are of a dark blue or purple hue, and a few others have been observed that are either green or brown.

The same material was also employed by the ancient Egyptian potters for the manufacture of innumerable small figures, and other objects, to be worn as amulets by both the dead and the living, together with bugles and beads of various sizes and forms, for which there once existed a demand so great, that they yet remain in prodigious numbers. The amulets comprise statuettes, on a diminutive scale, of the deities of the Egyptian Pantheon, with the sacred animals, and their various emblematic insignia; and they were adjusted to the requirements of the wearers, by being made in the form of pendants, studs, ear-drops, fibulæ, and rings. Concentric rows also were strung together, which would produce necklaces, bracelets, and anklets. Vast quantities of beads and bugles were used in forming the decorative or mystic network, so commonly placed about the mummies of the dead, and associated with amulets. The more elaborate of the beads that were applied to this singular use, were made in the form of different fruits and flowers, instead of having the spherical, globular, cylindrical, or annular forms more generally prevalent. In addition to the beaded-work, mummies have a pectoral ornament, also of enamelled pottery, which is almost universally in the form of an Egyptian pylon or doorway, and is decorated with different symbolical groups and figures, all of them having some sepulchral import. There yet remains to be noticed another class of sepulchral ornaments, of a kindred nature with the beads and bugles and amulets that cover the external bandages of the embalmed dead of ancient Egypt. These are the various other amulets and beads, which were evidently made for the express purpose of being suspended about the necks of the mummies. The figures introduced into these objects appear to have been selected upon some definite principle, and in conformity with a fixed rule; and they comprehend almost every mystic form or device that the Egyptians were wont to associate with the interment of their dead, and which were ordered to be placed upon certain parts of the body of the deceased, for the purpose either of conferring blessings or of averting evil. Finger-rings—*tebu*—formed

entirely of enamelled pottery, and adorned with characteristic and appropriate devices, were common in Egypt, and it is probable that they were used as well for sepulchral purposes as for the personal decoration of living Egyptians. Many of these relics that yet exist, are impressed with the names of well-known Egyptian kings, a circumstance that leads to the inference that these rings were worn, either in life or death, by personages of exalted rank, since the use of the king's name seems to have been restricted to functionaries of state—as the royal arms appear in England to have been introduced, in the middle ages, only into the monumental heraldry of those who had formerly held offices either immediately under the crown, or about the person of the sovereign.

The enamelled rings of Egypt, like the beads and statuettes and other decorative objects, were much prized by the Greeks and Etruscans. They have been found in the sepulchres of Etruria in settings of the exquisite gold filigree-work of the Etruscans, intermixed with precious stones and beads of gold, precisely as one would now testify admiration for the small cameo gems of WEDGEWOOD. In a tomb at the Polledrara near Vulci, in Italy, a heap of Egyptian beads and bugles was discovered, which had apparently formed a network covering, after the fashion of Egypt, to some bronze objects; but, the strings having yielded to the influence of time, the beads and bugles had fallen to the ground. Another tomb—one of those at Egyptian Thebes—contains a painted representation of the processes of finishing and stringing these simple and familiar objects. Three men are seen hard at work: one stands, and files bugles of green enamelled ware; a second is seated, with a basket full of these bugles before him, some of which he has arranged in a row for a necklace; and the third is drilling a hole in a piece of wood.

Their enamelled ware was employed by the Egyptians for the purpose of *inlaying* some of their figures, and for decorating their coffins by a similar process. In figures, when vitreous pastes were inlaid, says BIRCH, the portions made of this material were the extremities, as the fingers and toes, the beard and eyes, and parts of the dress, such as the collar round the neck, the bracelets, and anklets. One of the finest specimens of this application of the Egyptian enamelled ware in inlaying, adds the same able writer, is a head-dress or wig, found at Thebes, which formed part of a small figure of a king, probably about three feet high. The mass of which it is composed is of a deep-blue color, the fashionable head powder of the day being probably of that hue. So regular is the arrangement of the curls, that they appear to have been pressed out of a mould. A rich fillet or diadem, which passed round the head, is inlaid with small tesserae, about half an inch long and one-eighth of an inch wide, of bright-red paste, imitating jasper, and of gilded porcelain. In some instances the enamelled pottery is found to have been used with other substances, as ivory and various stones, for the purpose of inlaying. It was also applied to inlay a variety of domestic objects, some minutely small and others of a considerable size. The British Museum contains, besides other inlaid objects, a box of dark

wood, taken from a tomb at Thebes, that has on the lid and sides a square border formed of tesserae of blue enamelled pottery, alternating with similar pieces of ivory stained red. Two other remarkable Egyptian specimens in the national collections are tiles, one of which is rectangular and measures six by four inches; it is of the celebrated blue ware, on which is traced in a darker blue outline the figure of the royal scribe, ADMENEMAPT, worshipping OSIRIS; the other tile, which is circular, is inlaid with a very curious representation of a spider in the centre of its web.

Besides their enamelled beads the Egyptians have left, as illustrations of their social and domestic history, specimens of their draftsmen made of the same material, and various miscellaneous articles, that may have once been used either as personal ornaments, or as children's toys—the two classes of objects may often be grouped together—or for the various decorative requirements of daily life.

The same vitreous glaze which they used with such excellent effect in their enamelled silicious pottery, the Egyptians also applied with a similar aim to a vast number of works of a highly artistic character, executed by them in steaschist, or some other hard substance of the same kind. This steaschist, which closely resembles the jade employed by Chinese artists in many of their carvings, is a material that may be worked to great advantage by skilful hands. The Egyptians produced in it amulets, rings, and other objects, which are still distinguished for the sharpness and precision of their carving and their delicate finish. The stone, when cut and inlaid with niello-like incised work, was coated with enamel and subjected to the action of the furnace, the result being a species of glazed stoneware that at once bore a close resemblance to true pottery and was altogether distinct from it. Amongst the most highly finished and beautiful of the examples of these singular works of Egyptian art, that are known to be yet in existence, are signet rings and inscribed amulets. The form generally prevalent for rings executed in this manner is the scarabæus beetle, called in the language of Egypt *kleper*, or creator, and regarded by the Egyptians with peculiar reverence as the sacred emblem of the Deity, who made, as they held, all things out of clay. The hieroglyphics engraved upon these scarabæi are executed in flat intaglio, sometimes with a wonderful accuracy and delicacy, completely rivalling those on gems. On some only a solitary hieroglyphic is put; but on others as many as three lines of these symbols are inscribed. They are of all ages—from the fourth dynasty down to the Roman empire; the principal period of their manufacture was, however, the reign of TOTHMES the Third, of the eighteenth dynasty, one-tenth of these amulets bearing his name.—*Birch*. The same judicious writer directs attention to the fact, that many of these carved works attest a certain community of art in Egypt and Assyria. It is also observable that the devices, legends, and mottoes of the rings, amulets, and other objects clearly indicate that they were adapted to certain distinctive conditions of different classes of the Egyptian community.

The busy and enterprising multitudes who consti-

tuted the races that are now distinguished as ancient Egyptians, have transmitted both the salient points and the minor details of their national history and of their private life, in part written in their mystic hieroglyphics, and in part conveyed with graphic fidelity by means of the varied productions of their arts and manufactures. From both these channels of information it is evident, that a consideration of primary importance with the living Egyptian was the preparation and appropriate decoration and furnishing of his tomb. To this very circumstance posterity is mainly indebted for what is known, if not of Egypt, certainly of the Egyptians. They considered it to be right to adorn their sepulchral chambers with painted scenes and incidents, as they occurred daily on every side of them; and with the mummies of their dead they had been taught to deposit vases filled with various substances for the use of the deceased, together with a multiplicity of personal ornaments and other objects. Hence all these relics have come down preserved, as if for especial information, from century to century in their silent treasuries. The uses to which they were put by their makers have insured their preservation; and the relics themselves, in their turn, have reciprocated the good deed, by declaring in what manner the ancient Egyptians used them, and by elucidating the several purposes which they were intended to serve. Nor is the value of the ancient pottery, either preserved or represented amidst the remains of ancient Egypt, limited in its historical capacity to the land and the people of the Pharaohs and the Ptolemies. Certain fictile relics still in existence bear inscriptions which declare that they were fabricated to contain and to preserve tribute—*han*—of wine, incense, and the like, in the storehouses of the king; and there is every reason for believing that the same vessels conveyed these offerings from distant tributary lands to the banks of the Nile. The father of European history has left it on record that in his time—before CHRIST four hundred and forty years—wine was exported from Syria to Egypt in such amphoræ as are represented, tribute-laden, in the triumphal procession of TOTHMES III., and which may be seen in the national museum. Some of these very vessels, therefore, may have been sent to one of the last of the Pharaohs, who reigned in the lifetime of HERODOTUS; while others, in all probability, formed a part of the tribute paid to his more powerful predecessors. These productions of the potter may accordingly be regarded with a twofold interest, since they both call one back to the Egypt of antiquity, and also afford an insight into the condition of art amongst some Asiatic people, otherwise unknown, who were contemporary with the Pharaohs of the nineteenth dynasty.

ASSYRIAN POTTERY—With the exception of bricks both sun-dried and kiln-burnt, and of inscribed tiles and cylinders, the ceramic productions of the ancient Assyrians and Babylonians have not been discovered in any great numbers in Mesopotamia. Nor have the bas-reliefs and cuneiform writings—so far as the latter have been read—that recent researches have brought to light in this remarkable region, done much to elucidate the practice of the potter's art as it may be presumed to have

once flourished upon the banks of the Tigris and the Euphrates. The Assyrian sculptures are art-written records, not of the Assyrian people, but of their kings: hence, any illustration of Assyrian life that these most interesting relics may afford, is rather incidental and subordinate in its character, than a primary and direct motive of the composition. Not thus did the Egyptians apply their hieroglyphics. Their Pharaohs, indeed, appear in the full and significant grandeur of their pre-eminence; but with them their people are habitually associated. Egyptian life, in every phase of its varied conditions, and in all the diversified yet ever characteristic associations of Egypt itself, was what those active and imaginative sons of the Nile delighted to depict: and hence they stand alone amongst the nations of antiquity, in their love for that graphic species of history which records and transmits to distant generations complete biographies of a people.

In addition to the innumerable sun-dried bricks that were used for constructing the enormous mounds upon which the cities of ancient Assyria were erected, a few rude figures only of unbaked clay have been found beneath the pavement-slabs of the Assyrian palaces; and these were probably placed there as propitiatory offerings. The few objects of unglazed terra-cotta which have been discovered, consist of vases and other vessels of various forms and sizes, many of them being evidently made expressly for sepulchral uses, with some lamps of peculiar shape, and some small figures and architectural ornaments. Of these the larger portion may be assigned to different periods subsequent to the fall of Nineveh, while certain specimens have been found in circumstances which prove them to have been coeval with the ancient Assyrian edifices. One saucer-shaped patera LAYARD found built into the back of a wall of the N. W. Palace at Nimrûd, evidently through the mistake of the workman. Another vessel in the shape of a cylindrical jar, eighteen inches high, and nineteen inches in diameter, was found in the same palace between two colossal bulls at the entrance of a chamber; it is of a pale yellow clay, and ornamented with Assyrian mythological figures. Other vases were discovered inside sarcophagi, also made of earthen materials. Similar objects, the greater number being sepulchral, were picked up at Konyunjik above the ruins of the palaces in the mounds; they closely resemble the ordinary Roman pottery of the same class, and they were probably produced in Roman times, by the races who established themselves upon the huge mounds after the fall of the buried cities. Vases of the same class have also been found at Khorsabad, and examples of terra-cotta coffins have been exhumed at Kalah Shergat. The ornaments of all are of a very simple character, and there is but little to distinguish as Assyrian such of these works as are not unquestionably of a high antiquity. It has been remarked that this terra-cotta ware evidently continued to be made till a late period in the country that once had been Assyria, since vessels have been discovered there having covers inscribed with Hebrew and Syriac characters. The old Assyrians would certainly have written upon these vessels their own arrow-headed inscriptions. They may be as late as the fourth century after CHRIST. It must be added,

however, that it is by no means impossible for some few ceramic relics of the old Assyrian period to be intermixed amongst this more recent pottery. The terra-cotta figures and architectural ornaments of the Assyrians, like those of Babylonia, were probably coated with rich gilding, and consequently they may for this reason have perished through the cupidity of the spoilers. The few relics of this description that have been discovered are small in size, and by no means worthy of high admiration as works of art. Besides the figures, some moulds for making small figures have been found formed of terra-cotta—also some seals, now in the British Museum, about an inch in diameter, of which the material is fine dark clay, and which had been stamped with the device of a king stabbing a lion with a sword. LAYARD informs us that in removing one of the slabs sculptured with the hunting scenes of Ashurbanipal at Kouyunjik, several small terra-cotta figures of dogs were found, standing, made of a coarse clay covered with a blue, red, or black paste, and having names inscribed on them in cuneiform characters, such as, *the guardian of the house, the lion-tamer*, and others. RAWLINSON supposes these to be images of certain hounds, formerly favorites with the king, which had been killed in hunts of lions and other wild animals.

Very different from the formulæ which they impressed with stamps upon their kiln-baked bricks were the legends that, in accordance with a custom peculiar to themselves amongst the nations of antiquity, the Assyrians inscribed upon cylinders, prisms, and small tiles of very fine and sometimes highly-polished terra-cotta. Thus they wrote the records of the king's victories and the annals of his reign; thus their title-

deeds, and deeds attesting and confirming the sale of land and other properties, were written; and thus their astronomers noted down the results of their observations and calculations. A chamber filled with terra-cotta archives and miscellaneous records—books, they would now be called—was found in the palace of SENNACHERIB at Kouyunjik, one of which, a hexagonal prism of terra-cotta, inscribed with the records of a king's reign, now deposited in the British Museum, is represented in Fig. 432. Probably this chamber was the



private library of that monarch. Similar collections have been discovered in other parts of Assyria, from which there have been obtained about twenty thousand inscribed tablets, containing the native literature of the country as it issued, not from the press, but from the kiln. Thus, while the paper and parchment learning of the Byzantine and Alexandrian schools has almost disappeared after a few centuries, the granite pages of

Egypt and the clay leaves of Assyria have escaped the ravages of time and the fury of barbarism.

In addition to their terra-cotta writings, the Assyrians, in common with the Egyptians, employed the same plastic material that formed their cylinders precisely in the same manner as sealing-wax was used in Europe in the middle ages, and is still in use at the present day. The clay, when in a moist state, was either impressed upon the face of the document, or appended to it by means of a slip or cord. One of these seals, found with the terra-cottas supposed to contain the royal archives at Kouyunjik, was stamped with the signet of SABACO, who reigned in Egypt seven hundred and eleven years before CHRIST, and was contemporary with SENNACHERIB.

Glazed and Enamelled Pottery was evidently in use amongst the Assyrians for various religious, sepulchral, domestic, and architectural purposes, much in the same manner as with the Egyptians. The Assyrian productions of this class, however, are proved by such remains of them as still exist to have been inferior to those of Egypt, both in their manufacture and in their artistic qualities. Very few vases of this ware have been found in a state of good preservation amidst the wreck of the Assyrian palaces; but fragments abound in that country of ruins, which demonstrate the existence of this ware in ancient times under a considerable variety of forms, though never, as it would seem, in any great abundance. Some of the shattered fragments now in the British Museum are parts of vessels that were lined with a coarse blue glaze; others, found in different localities, are of a pale lilac hue, or they have yellow patterns on a blue ground; or the ground is white, upon which there are stripes of brown and purple: but the most prevalent color is a fine bright blue, verging towards a green when the surface has been slightly decomposed. The body of this ware is formed of the fine clay deposited during the inundations of the great rivers, the glazes being a vitreous silicated substance variously colored with metallic oxides. A recent analysis has shown, that the opaque white employed in the decoration of an Assyrian enamelled brick was produced with tin, the yellow with antimoniate of lead, the brown with iron, and the blue and green with copper; the flux and glazes proved to consist of silicate of soda and lead. The enamel—as was proved to be the case from its having trickled down the sides when in a melted state—was placed only upon one surface of the brick, with the view to securing its adhesion; and the brick itself was laid horizontally, with the enamelled face uppermost, when in the furnace. This brick was probably slightly baked before it was painted, and then when the colors had been applied to it after it had become cold, it was a second time placed in the furnace. The walls of Nimrūd were evidently faced with these enamelled bricks, that were variously colored and otherwise decorated, and thus formed an effective species of mosaic. Architectural cornices and other decorative accessories were also formed in a somewhat similar manner from different pieces of this enamelled terra-cotta.

BABYLONIAN POTTERY.—In their construction from sun-dried bricks almost identical with those that were

raised by the Assyrians higher up the streams of the great rivers, the vast ruined mounds of Babylonia yield various ceramic relics, that bear a close general resemblance to the corresponding remains which have been discovered under similar circumstances in Assyria. These examples of pottery are not sufficiently numerous to supply detailed information respecting the fictile processes of Babylonia. The pottery of these mounds, also, is composed of productions of very different periods, the works of distinct races. Some without a doubt was made in the days of Babylonian greatness; but the greater portion must be assigned to eras subsequent to the fall and ruin of the city and empire of the Chaldees, when various races succeeded each other in the occupancy of what once had been Babylon.

The eups, vases, and other vessels of terra-cotta in use by the Babylonians, appear to have been of a simple character. The paste is generally of a light red color, but sometimes of a yellow hue, with a tinge of green; and it has not been submitted to the action of a very high temperature. The figures were produced in moulds; and the vases, formed upon the wheel, were devoid both of painting and any other decoration. In the case of the larger specimens, modelled figures and heads were sometimes introduced at the handles for the purpose of adornment. A few small pieces of very fine terra-cotta have been found in this region, in the form of bas-reliefs of great interest. One, the best of the series, now in the British Museum, represents a man holding by the collar a very large and noble-looking dog. The design has been modelled by the hand, and it is remarkable for its spirit and freedom. This specimen was obtained near Babylon. Other small bas-reliefs of female figures have been found at Warka; but they have all been produced from moulds, and may be assigned to a less remote period. The larger statues, such as would be made to represent the gods and heroes of Babylon, may be considered to have been formed of terra-cotta. Such was the image made of clay and metal, recorded by DANIEL to have been seen in his dream by NEBUCHADNEZZAR; and such, too, was that other image of Bel, declared by the same prophet to have been composed of clay, and then covered with a coating of brass or bronze. The colossi mentioned by DIODORUS, were probably produced in the same manner; and the famous golden idol of NEBUCHADNEZZAR may have been a work of the king's potters, overlaid—as was the custom amongst the Babylonians—with rich and costly gilding.

Gilding, overlays of silver, and variously-colored glazes were applied by the Babylonians to the bricks with which they constructed their more important edifices. The walls of the Median Eebatana are described by HERODOTUS as having been built with bricks of different colors; and the supposed temple of Belus at the Birs Nimrūd affords another remarkable instance of the same polychromatic construction. In 1854, Sir H. RAWLINSON dug out from the angles of the stages of the brickwork three inscribed cylinders, from which he has discovered that the Birs Nimrūd was dedicated by NEBUCHADNEZZAR to the seven planets; the building was, accordingly, constructed in seven stages or platforms, each one smaller than the one below it,

and formed of bricks differently tinted. Mr. LOFTUS has added much very valuable information to what had been previously ascertained upon the subject of Babylonian pottery. At Warka he found walls formed of sun-dried bricks, banded at intervals with layers of reed; some of these bricks were stamped with inscriptions. Kiln-dried bricks of small size, and red brick cones similar to those constantly to be seen in Egypt, were discovered at the same place; the latter had their bases colored red, and they were embedded in a cement of mud and straw as building materials. At Warka, also, Mr. LOFTUS found an edifice built of similar cones, three and a half inches long, and laid horizontally, their crests and bases alternating, and embedded in cement. They were formed of a dull yellow clay; but, their bases having been dipped in black or red paint, they thus might be arranged in such a manner as would form various ornamental patterns. Ornamental brickwork constructed of bricks of the ordinary shape and executed with singular skill, together with enamelled bricks of various hues decorated with stars having seven rays: a pavement of vitrified slabs; glazed lamps of terra cotta; and most curious coffins of enamelled ware in the shape of gigantic slipper-baths—were amongst the fictile relics discovered by this indefatigable explorer at Warka, which appears to be identical with the ancient Ur of the Chaldees. The Warka coffins were found in prodigious quantities, piled up to the height of forty-five feet. They were formed of pale straw-colored paste, imperfectly baked; the whole being covered with a blue glaze that has acquired a greenish hue through age. These singular relics Mr. LOFTUS assigns to the Sassanian period of Babylonian history, when Warka must have been a vast necropolis; they are variously ornamented with raised bands and patterns, and also with numerous small figures in low relief, and they have richly adorned lids of the same material with themselves that cover the openings. Several specimens have been added to the oriental collections in the British Museum.

Fragments of glazed or enamelled pottery are intermixed with the debris of the common terra-cotta wares throughout the ruins of ancient Babylonia, and they consist of the remains of vases and different vessels in addition to the colored bricks so much in favor with the Babylonians.

Documents inscribed upon cylinders and slabs of fine terra-cotta after the custom prevalent amongst the Assyrians, have been discovered in the ruinous heaps that have of late attracted so much attention in the ancient Babylonia Proper. These terra-cottas exhibit great varieties in their forms, but, so far as they have been deciphered, appear to comprise precisely the same classes of records with those of Assyria. In one fragment, at the edges there are the names and seals apparently of the witnesses who attest a deed. Another fragment of the utmost value is a part of a great cylinder, now in the museum of the India House, and containing, according to Sir H. RAWLINSON, a transcript of the statistical tables of NEBUCHADNEZZAR, in which the temples either built or endowed in Babylonia by that monarch are enumerated. Several other Babylonian cylinders are preserved in the various museums of Europe. Sir H. RAWLINSON states that they are seven in number, or

rather that there are seven distinct historical records preserved on as many different cylinders. Of these records, the one that describes the Birs Nimrūd, is repeated in each of the three cylinders that he himself discovered in that celebrated heap of ruins.

ETRUSCAN POTTERY.—As in Egypt and Assyria, so also in Europe, the first appearance of the potter's art is coeval with the first dawn of civilization. In Etruria, that region of Italy which lies to the north of the Tiber, from a remote antiquity the remarkable race were established who gave their name to the country where they flourished, and whose half-legendary history is the earliest that appears in European annals. It is a custom prevalent amongst writers upon ancient art, to describe the Etruscans as having obtained from Egypt the original germ of all their art-industries; it would, however, be difficult to demonstrate the fact of any intercourse between Etruria and Egypt, antecedent to the earliest operation of Etruscan art. The fact appears to be that the Etruscans, like every other people, *in the first instance*, were the inventors of their own arts, and applied their inventions to meet the requirements of their daily lives. It is true that there is conclusive reason for considering the sombre and severe spirit of the Etruscan race to have been rather receptive than productive; and, consequently, this remarkable nation is found readily to have accepted and appropriated to its own use whatever improvements in the arts it might have discovered during the progress of time, through a gradually-extending intercourse with foreign visitors. Thus the arts of Egypt, transmitted through the Greeks, may be said ultimately to have reached Etruria; and thus the Etruscans, having been instructed in their style by the artists of Greece, conformed to the Greek system, and in fact appropriated it as their own. But, on the other hand, it is no less certain that the primitive Etruscans were possessed of sufficient inventive powers to produce an indigenous pottery suited to their own wants, and the materials for which nature had strewed in abundance at their feet.

The earliest, and as would naturally be expected, the simplest relics of Etruscan pottery that yet remain, must be attributed to an era long subsequent to the general practice of the ceramic art in Etruria—that is, they appear to have been produced in the eighth and seventh centuries before this era. They chiefly consist of vases of a dark color, fabricated from a coarse brown ware, and in some instances apparently modelled in imitation of vessels formed of wood. These vases vary considerably in size, and many examples are adorned with figures in relief; but no instances have been observed in which paint was used as a decorative medium. They have been for the most part discovered at Cervetri—the ancient Cære—Vulci, and Chiusi; and it is evident that they were not by any means first efforts in the practice of the potter's art. Indeed, seven hundred years before CHRIST, the Etruscans had been a flourishing people. It is a subject for much regret that the history of European pottery, which opens upon Etruscan ground, should not be able to trace out its course clearly from its original fountain-head; but the antiquity of Etruria, as a country regularly inhabited by a race who enjoyed at least a comparative civilization,

intercepts the researches of the historical inquirer, and convinces him that he must be content to commence his record with the earliest actual specimens of Etruscan fictile works, that time has been willing to transmit to the present age. The want of a literature amongst the Etruscans, also, adds seriously to the difficulties which attend the investigation of the ancient arts of Etruria. Roman writers, however, have supplied much information that might naturally have been expected from the Etruscans themselves. It is chiefly by this means that the knowledge possessed of the more important works of the ancient Etruscan potters is derived, since the Romans, in the early days of Rome, unable to execute such works, were obliged to have recourse to Etruscan artists for the plastic decorations of their temples. Such testimony is conclusive in establishing the fact, that the Etruscans at a very early period had established a school of art peculiarly their own, which, in its characteristic features, had attained to a high degree of perfection.

According to PLINY, the art of working in terra-cotta was principally cultivated at an early period in Italy by the Etruscans. The same writer states that the art of statuary was so old in Italy that its origin was unknown. One may reasonably infer that in the days of PLINY the origin of the potter's art in Europe was equally obscure; and thus, accordingly, it may be safely conceded to the Etruscans—the people amongst whom that art appears to have been known and practised from a remote antiquity. BIRCH suggests that the Etruscan potters may have worked from foreign models, and perhaps from the statues of the Egyptians, with which they first became acquainted when PSAMMETICUS I. threw open Egypt to the commerce of the world in the second century of Rome, six hundred and fifty-four years before CHRIST. But Etruria had attained to celebrity for its pottery before Egypt had been made accessible by Etruscans; and, in fact, there exists no really valid reason for withholding from the Etruscan potters the credit of producing their own pottery from their own designs, until the potent influence of Greek art appears to have prevailed over the native sympathies of the Etruscan people. The change thus effected may be said to have taken place during the first half of the fifth century previous to the Saviour. Prior to that period the arts of Etruria may be regarded as Etruscan, and therefore independent of Hellenic influence.

With the exception of vases, of which vast numbers have been found, but few productions of the Etruscan potters have been preserved until the present day. The safety of the vases has been the result of the free use made of them by the Etruscans themselves in their sepulchral rites. They deposited numerous vases in their tombs, and closed them up in the same security that they so studiously sought to obtain for the remains of their dead. And the fictile relics rested undisturbed for centuries, until the inquiring and exploring spirit of modern times should exhume them as monuments of ancient history. The statues and reliefs in terra-cotta for which the Etruscans were celebrated, with their architectural works executed in the same material, would almost inevitably perish in the sharp vicissitudes of succeeding years; and, indeed, such examples

as do exist owe their preservation to the circumstance of their having been deposited, like the vases, beneath the surface of the ground.

Bricks and tiles appear to have been but little used by the Etruscans, except for sepulchral purposes. The recesses of the chambers that held the small sarcophagi within which the ashes of the dead were deposited, were closed by tiles bearing inscriptions; and similar tiles, at a much later period, were used to cover such bodies as were interred, and not burnt. Various decorative accessories of the tombs of an architectural character, were also modelled in terra-cotta; and there is every reason for believing that friezes, antefixæ, and other architectural details formed of the same material, were in general use. Recent excavations in Etruria, however, have failed to produce examples of genuine architectural bas-reliefs, such as were so freely introduced into their buildings by the Romans. Terra-cotta sarcophagi have frequently been found, which are identical both in their general character and their style of adornment with the more costly works of the same class in alabaster, tufo, and other similar materials. Some few are of sufficient size to receive a human body laid at full length. The British Museum contains two such sarcophagi, which have been obtained from Vulci: their sides and ends are covered with bas-reliefs, and on the covers there repose recumbent effigies of Etruscan females, modelled at full length. The paste of which these terra-cottas are composed, is either a pale red or a pale yellow in color. But Etruscan terra-cotta sarcophagi more generally are very small, and appear at first sight to be models rather than actual depositories of the remains of the dead. They were intended to be the receptacles of the ashes after cremation, and they may be regarded as the prototypes of the sepulchral urns which the Romans ranged in rows of small cells or niches, around their *columbaria* or sepulchral chambers.

The effigies that rest upon sarcophagi are the only statues of full size in terra-cotta by Etruscan artists, which are known now to be in existence. The few examples that have been discovered closely resemble in their artistic treatment the early bronzes and sepulchral wall-paintings of Italy. It does not follow from this circumstance that the terra-cotta figures were modelled from types either in metal or from paintings; on the contrary, the resemblance between these figures, executed by different processes, simply confirms the independent and consistent action of the artists of Etruria. A most remarkable recumbent effigy in pale red terra-cotta, having the clay intermixed with volcanic sand, was found at Cervetri, where other somewhat similar figures have also been discovered, all of which are genuine Etruscan, and apparently older than the foundation of Rome. Besides the monumental figures, some few curious and interesting busts have been found, formed of clay, in the sepulchres of Etruria.

The VASES of the Etruscans admit of the following classification:—

1. Vases of brown terra-cotta.
2. Vases of black terra-cotta.

3. Vases of red terra-cotta.

4. Vases painted.

Also a small class of vase of a yellow ware.

The brown vases have already been stated to be the oldest existing specimens of Etruscan pottery. Their color is a greyish brown, and sometimes the clay is red in the centre. They are in various shapes, the most curious being an example in the British Museum in the form of a *Tugurium*, or ancient Etruscan cottage—Fig. 433—with a movable door and a vaulted roof that

Fig. 433.



apparently was intended to represent the beams of the timber-covering of an actual dwelling. The ashes of some deceased Italian, who may be considered to have lived and died before the name of Rome had been spoken amongst men, were inserted through the door, which was then secured by a cord. The smaller vessel was then placed within a large two-handled vase of equally rude character, and thus protected from the superincumbent mass of earth.

It is a remarkable fact that hut-shaped sepulchral urns have been discovered in several parts of Germany, which closely resemble those that once were buried in the tombs of Etruria. The German specimens are distinctly Teutonic; and they are to be attributed to an age before the predominance of Roman art, but while bronze weapons were in use. One found at Mount Chemnitz in Thuringen, is cylindrical with a conical roof or cover; a square orifice in this vase represents the doorway or window of the hut, through which the ashes of the dead were introduced, when the whole was secured by a small door fastened with a metal pin. Similar vases have been exhumed at Roenne, Parchim, and in the island of Bornholm. A vase of this description, found at Aschersleben, has its cover modelled in the form of a tall conical thatched roof, and it has the door with its ring still remaining. Another, with a taller body and flatter roof, with a door at the side, was discovered at Klus, near Halberstadt. The larger vases were used to contain and preserve the ashes of the dead; and they are found in some instances to have been placed, for greater security, within vases of coarser fabric and a different shape, or to have been protected by some covering of stones or tiles. The

other smaller vessels held the offerings, consisting of different viands, that the Teutonic races deposited with their dead.

The ancient brown vases of Etruria are not uncommonly found beneath beds of lava. Many of them are highly polished by friction, so that they have the appearance of basalt, but they have no glaze upon their surfaces.

Next in the order of time are the black vases, some of which are thick and heavy, while others are thin and light. The black surfaces of many of these vases have a lustrous jet-like polish, which occasionally may have been produced upon the lathe. They frequently exhibit traces of the imitation of other Etruscan works of art in both wood and metal; but they show no signs whatever of any imitation of foreign productions. In the earliest examples the ornamentation consists simply of rude zigzags, spirals, and festoons of lotus-like flowers and similar devices, hatched upon their surfaces. Somewhat later animal forms, with human figures, heads, and other objects, make their appearance. These figures are commonly disposed so as to form friezes running round the body of the vase. They are generally in a bold relief, which has been obtained either from the impress of dies, or by modelling, or by passing a cylinder cut in intaglio round the vase while the clay was moist. The treatment of the figures in these friezes is peculiar, and it not uncommonly indicates that the rudeness of the work has resulted rather from the intractable nature of the material, than from the incapacity of the artist. The early usage of producing ornaments by means of incised lines, is occasionally introduced for the purpose of carrying out the details of the reliefs. The designs of these friezes are obscure and uncertain; and, in connection with the absence of inscriptions having reference to either the subjects, the artists, or the potters, they serve to corroborate the assumed high antiquity of the vases. When inscriptions do occur, they appear to be merely the potter's memoranda, which were scratched in with a pointed instrument at the bottom of the vases after they had been finished. Vessels differing very greatly from one another in form and size, and evidently no less different in their several uses, have been found of this ware; amongst them are cinerary vases of the most singular character, being rude representations of the human figure. Collections of these vases have been found in many sepulchres, which contain various vases and other objects, the use of which is unknown. Large vases sometimes contain numerous smaller ones; spoons also and vase-stands have been found with them. It is probable that JUVENAL referred to pottery of this class, when he spoke of the *black saucer of Numa*; and that this is the black ware that PLINY records to have been fabricated by the corporations of potters in the days of NUMA, seven hundred years before CHRIST. HORACE, MARTIAL, and JUVENAL also appear to have had it in view in certain well-known passages of their writings. The tombs which have produced these vases in the greatest abundance are in the vicinity of the ancient Veii, Cære, Clusium, and also at Volaterra and Cortona; but they very rarely occur to the south of the Tiber. An analysis of the

paste of the black Etruscan vases has given a mean result of—

	Centesimally.
Silica,.....	63·24
Alumina,.....	14·42
Oxide of iron and manganese,.....	7·80
Carbonate of lime,.....	3·25
Carbonate of magnesia,.....	2·12
Carbon,.....	1·83
Water,.....	7·34
	100·00

The vases of red ware, which may be assigned to the earliest period of existing Etruscan pottery, are found in the same ancient sepulchres with the black vases, but in much smaller numbers. These vases are of a dull red hue, and of a gritty material, apparently containing an admixture of the tufo of the soil. If large in size, their bodies are reeded, and ornamental patterns are boldly modelled about their necks; sometimes they have handles; and the characteristic Etruscan frieze appears in some of them, with representations of animals, chariots, hunting scenes, and banquets. They generally are found standing in flat circular dishes or saucers, of similar ware, but made of a finer paste, and ornamented with other friezes impressed upon them in bas-relief with a cylinder. Some few vases of this class, instead of a decided red, are of a pale salmon tint; and they have a slightly freckled appearance, which is produced by black specks of some volcanic substance mingled with the clay. The Etruscan sepulchres also continually produce vases of a pale yellow color and of a fine quality, some of which are probably of very ancient date, while others appear to have been manufactured at subsequent periods.

Some vases found at Cære, composed of a pale reddish-brown clay, specked with black volcanic sand, and sparkling with mica, are amongst the earliest specimens of the *painted* pottery of Etruria. They are adorned with various patterns, and also with flowers and figures, painted in white upon a black back-ground, or upon the clay in its natural color; the peculiarity of the work being that the painting was executed after the manner of an opaque fresco, and not burnt in upon the vases in the furnace. These painted vases may have been produced a century or more anterior to the mythic arrival of the Greek potters, who, according to PLINY, were brought by the fugitive DEMARATUS from Corinth to Etruria between the years five hundred and twenty and six hundred and sixty before CHRIST. To this incident has been attributed the first introduction of archaic Greek vase-painting amongst the Etruscans. The Etruscan sepulchres have yielded many vases having pale buff back-grounds, upon which figures of animals are painted with fantastic and floral borders, all in a deep-red, that may be assigned to this period.

Next in the order of chronological succession are the red or orange-colored vases with black figures, the subjects being generally mythological, and the execution of them indicative of at least some progress in the art of pictorial representation, though still there is much of rudeness that lingers about them in combination with a strange uncountness in many of the figures. In other examples the adjustment of the colors is reversed, and

the figures are red upon a dark ground. These figures are relieved by lines of black, obtained by cutting down through the red pigment to the black glaze of the vase. This same arrangement of the tints prevails in the finest and most perfect specimens of Etruscan and Italo-Greek vase-painting. The figures are red upon a ground of polished black. These vases were produced after Greek art had found a second home in Italy; and, consequently, though both made in ancient times and at the present day discovered in Italy, they may be classed with the works that were produced by Greek ceramic artists. The shade of the ground in some of the Etruscan vases is a dark-brown; in others the clay is ash-colored; and in both cases the designs are painted in black and crimson, with incised lines executed with a graving-tool, to mark the outlines of the figures with more distinctness, and also to impart the effect of energetic action to the development of the muscles. The figures are very generally represented on a ground *semée* with flowers. In addition to those vases found in Etruria, which must be distinguished as Italo-Greek from their having been made by Greeks resident in Italy, many imitations of Greek vases of every kind were made by Etruscan potters throughout the period in which their own artistic powers were experiencing a continual decline. In these examples certain Greek attributes are rendered after an Etruscan manner, and the whole work is destitute of both originality and feeling. The subjects generally show traces of Etruscan influence, and often resemble the relieved friezes of the true Etruscan solid black ware. A paler ware was also manufactured at the same time, with unimportant subjects, and figures badly drawn and painted of a pallid tint, and with a glaze of a leaden hue. Other pale vases of still later date have been found in the sepulchres of Orbetello and Volaterra, with figures armed after the Roman fashion, painted of a light tone, the accessories being white, and the glaze devoid of lustre; and, in their turn, these last vases are succeeded by others, in which various figure subjects, with old Latin inscriptions, are painted in opaque white upon a black ground. Their date is about two hundred years before CHRIST.

The *inscriptions* which are associated with the subjects that appear upon Etruscan vases, like those on the Greek, are either painted in an opaque white or red upon the glaze, and are descriptive of the figures and incidents represented in the paintings, or they are incised; in the latter case the inscriptions generally refer to the proprietors of the vases. Many of these inscriptions are very difficult to read, from the rudeness of the Etruscan language in which they are written, and also in consequence of the obscurity of the legends themselves.

The same sepulchres that have supplied such abundant and diversified stores of the ceramic productions of the ancient Etruscans, have also preserved numerous examples of their exquisitely engraved gems, of their noble bronzes, and their beautiful and delicate gold filigree work. However admirable many of their vases may be, with their pottery the Etruscans never were so successful as with their works in metal. And the Etruscan artists evidently felt that they were able to

exercise a more complete mastery over metals than over clay, since it is found that in their best and most characteristic pottery they have assimilated their fictile productions to their bronzes. This assimilation ceased as soon as the ceramists of Greece had established themselves in Etruria. From that time the Etruscan potters conformed to the Greek system, and the finest ceramic works that thenceforth were produced in Etruria must be distinguished as Etrusco-Greek—they were the productions either of Greeks who had settled in Etruria, or of Etruscans who had been instructed and directed by Greeks. The grand distinction, then, between the two great classes of Etruscan sepulchral deposits is this, that the most admirable pottery is Etrusco-Greek, while the best metal-work is genuine Etruscan. Still, in the same deposits pottery is found in abundance, which is no less truly Etruscan than the works in metal, and which, at the same time, possesses many qualities that are eminently meritorious. In treating of the pottery of Greece, it will appear that the most precious relics of that wonderful art-manufacture have been discovered in far greater numbers in Italy than in Greece itself. In Etruria the Greek settlers produced in abundance a pottery that was thoroughly Greek, and their Etruscan contemporaries both imitated their productions and conformed to their style. A few lingering traces of the old native feeling and association may occasionally be discerned in vases, which appear to indicate that they were produced by Etruscans in Etrusco-Greek times, while the Greek style was in the ascendant, and yet before Etruscan usages and habits had been altogether superseded. It is remarkable that, in the prolific deposits which have been discovered wherever the cities and cemeteries of Etruria have been explored, vases have been found that were genuine Etruscan in the same group with others no less essentially Greek. At Corneto, the ancient Tarquinii, the discoveries have been rich in the most characteristic specimens of pure Etruscan vases, black and solid, with embossed figures. The same may be said of Sarteano and Perugia, and more particularly of Cervetri or Cere, and of Veii, now Isola Farnese, and of Vulci, or Ponte della Badia. At Veii and Vulci, with the embossed black ware, painted vases and others of every variety produced in Etruria have been found. The sepulchres at Vulci have also yielded immense quantities of plain solid black vases, and of others that are painted black only, which were found in immediate association with bronzes, ivories, gold filigrees, and other objects peculiarly Etruscan. And, with these evident relics of the native pottery of Etruria were discovered, in equally great numbers, vases of the Italo-Greeks in the utmost variety, and of the highest excellence. These vases were in all styles and of all epochs of art, including both those with maroon figures upon buff grounds, of the primitive archaic period, and the various productions of the latest decadence. The sepulchres themselves were most simple and unpretending; but their ceramic contents, which for the first time were systematically explored in 1829, have never been surpassed in value and interest. The finest known specimens of vases with black figures, including such as have the black figures represented upon white

grounds, have been found at Vulci. No less remarkable also for beauty of form, for excellence and energy of drawing, and for the vivid richness of their glaze and color, are the Vulcian vases with red figures. The numerous inscriptions, also, with which these vases abound, and the occurrence in them of subjects new to classical authorities, combine with their admirable artistic qualities to enhance their importance; so that these deposits may be considered to have effected more for the advancement of our knowledge, not merely of ancient pottery, but of ancient art also, than any previous discoveries. Very remarkable discoveries of Greek pottery have been made in many other parts of Etruria, but none that may be put into comparison with those that disclosed the long-hidden treasures of Vulci. Many of the finest and most characteristic specimens from almost every principal discovery in Etruria, have been added to the ceramic collections of the British Museum.

GREEK POTTERY.—Under this collective term it will be understood that the productions of Greek ceramic artists are alike comprehended, whether their works have been preserved and discovered within the limits of Greece, or either to the West or East of Greece Proper, in Italy and Asia Minor. Whatever the region that may have produced it, as the result of modern investigations, in all true Greek pottery the impress of the arts of Greece is equally apparent; and all the relics of those arts may, accordingly, with the most strict correctness, be grouped together.

The Greeks resembled other nations in their having established a pottery manufacture of their own for their own use, at the earliest dawn of their history, and, indeed, before their history had succeeded to the era of mythic legends. The earliest productions of the Greek potters also, like those of other countries, comprised works in the three varieties of sun-dried clay, kiln-baked terra-cotta, and a similar terra-cotta covered with a glaze, which last class of fictile productions has commonly, but erroneously, been designated porcelain. In addition to building materials, the ancient Greeks formed various objects in sun-dried clay, which they applied to the internal decoration of their temples and dwellings; and PAUSANIAS has recorded the existence in his time of a statue of PROMETHEUS in this material. As a matter of course, these fragile productions have long ceased to exist, and have left the practical elucidation of the pottery of the Greeks to those other works which, instead of representing the lineaments of PROMETHEUS himself, have acquired both strength and durability through the action of the Promethean element, fire.

The use of simple unglazed terra-cotta amongst the ancient Greeks was very extensive. It provided for the requirements of daily life, and it was equally ready to supply what might be demanded for more important purposes, whether in religious and votive matters, or in connection with incidents of public interest, or for every species of decoration. Terra-cotta, also, was in constant request with the Greeks in connection with their sepulchral and commemorative usages. Friezes and other architectural members of the Greek temples were, in some instances, executed in terra-cotta; but

the examples that remain in Greece are of a period after the establishment of the Roman dominion, and those of Southern Italy and Grecia Magna can scarcely be considered purely Greek. Statues, statuettes, and miscellaneous figures, with bas-reliefs, and other objects in more salient relief, were produced in the same material in great numbers. Terra-cotta was also employed by the sculptors and other artists of Greece for modelling their compositions, before they proceeded to execute them in more costly materials. Objects of various kinds in terra-cotta once existed in immense numbers at Athens, as may be inferred from a passage of Demosthenes. It appears that there were competitive exhibitions of these plastic works at Athens and the other cities of Greece on certain festive occasions, a circumstance that will account for the artistic excellence to which they commonly attained. Such works continued to be produced until a late period of the Roman empire; and yet, but few examples of fine Greek terra-cottas have been handed down. They were but sparingly used in the tombs, and, therefore, they have perished amidst the wreck of shrines and palaces; and with the homes of the Greeks who made and fashioned them, they have disappeared from the face of the earth. Neither have the terra-cotta moulds, that were certainly used for the casting of bronze statues, been discovered. Small figures, however, made by the same process by inferior artists, which once were used by the Greeks as ornaments or as household gods, and which closely resemble modern plaster casts, have been found in abundance near the sites of many of the cities of antiquity. The paste employed in producing their terra-cotta figures by the Greeks, is distinguished from that of the vases by its being softer and more porous. It yields easily to the touch of a steel instrument, and emits a dull sound when struck; nor does it attain to any great degree of hardness when submitted to a high temperature. Its color varies from a deep-red to pale-straw; and a similar degree of variety may be observed in the texture and density of objects from different localities. The terra-cotta of antiquity may be distinguished from modern works of the same class, by its greater lightness as well as by its softness.

The terra-cotta figures and architectural ornaments of the Greeks, were constantly painted by a body of artists who appear to have devoted themselves entirely to such occupations. They adopted both a conventional system of polychromatic adornment, and also such coloring as might be considered to have been based upon the natural and appropriated distribution and harmony of the different tints. Gilding was occasionally introduced, though, as it would seem, only with a sparing hand. The colors employed were apparently in most cases derived from coarse earths, of the same kind as those from which the ware itself was fabricated. Colors of metallic origin were more rarely introduced. Egypt supplied smalt for the cerulean blue; a Cyprian blue was also used, and subsequently indigo. Other colors were obtained from various parts of Greece, or from Greek colonies and dependencies. PLINY, as quoted by BIRCH, speaks of a painter upon terra-cotta in the words, *figlinum opus encausto pinxit*; but it has

not yet been ascertained whether any examples of encaustic painting upon Greek terra-cotta have been discovered.

Amongst the almost innumerable variety of objects that the ancient Greeks made in terra-cotta, were small cones or pyramids, about three and a half inches high, and perforated near the top. They were commonly inscribed, and they are supposed to have been attached to the necks of cattle. They are frequently found in the fields in Attica and other parts of Greece. Similar cones have also been found, which are perforated vertically. Some specimens, almost of a bell-shape, were discovered near Sebastopol and at Kertch. Small flat discs of pale-red or yellow terra-cotta, pierced with two holes, and ornamented on one side with a star in relief, and with the letters A and E on the other side, have been found in excavations at Tarsus. Others have been discovered in Lycia.

The Greeks habitually made from baked clay the lamps which provided light within their dwellings. They are found to have assumed a great variety of shapes, many of them exactly resembling those discovered at Rome, and others differing most essentially both from the prevailing Roman types and from one another. The distinguishing characteristics of the Greek lamps, are the superior fineness of their paste, and its paler hue after leaving the furnace, their smaller size and more delicate art, and, above all, their inscriptions. The Greek lamps of terra-cotta that have hitherto been discovered are all of the period of the Roman dominion, and consequently they may be grouped with corresponding works produced in other parts of the empire. In the neighborhood of ancient Greek cities they exist in great numbers. Several hundreds have been taken from excavations at Tarsus and at Calymna, and many other places have been almost as prolific in these interesting fictile relics of the Greeks.

GREEK VASES.—Fictile vessels of various shapes and sizes were employed by the Greeks, as they were by the Egyptians, for every conceivable purpose which it would be possible for them to accomplish. They performed the several duties which are, in this country, assigned to casks, boxes, cases of whatsoever kind, baskets, and such articles of furniture as are intended to contain and preserve different articles, as well as those offices which are considered to be peculiarly appropriate to pottery and porcelain. The vases of the Greeks accordingly admit of a ready classification, not only in their artistic capacity and their chronology, but also in reference to the uses which they were severally intended to fulfil. By far the greater number of these vases was decorated with painted figures and various devices, and their surfaces were covered with a glaze; but there were some varieties of vases which, in addition to the glazed examples of the same classes, were made in great quantities in simple unglazed terra-cotta. The most capacious of these terra-cotta vases, were tubs or casks called *pithoi*, and they were calculated to contain enormous quantities of wine, honey, corn, or other stores. They have the shape of either oblong or globular caldrons, with wide mouths. When full the *pithos* had its mouth closed with a large circular stone entitled *kithon*. Fragments only of *pithoi* have

hitherto been found in Greece itself; but Italy has yielded some complete specimens of gigantic dimensions. Others have been discovered in Asia Minor, and still more recently in the Crimea. They were constructed by a peculiar process, which may be described as plastering the clay upon a frame-work of wood. The *pithoi* are best known from the circumstance of Diogenes having established himself in one of them, as in a domicile well suited to the simple requirements of a philosopher, from which he stretched out his body on the occasion of his celebrated interview with Alexander. This incident is represented in some works of ancient ceramic art—Fig. 434—one of them, a fragment of a lamp, being in the British Museum.

The terra-cotta vase that was in most general use, both for commercial and domestic purposes, was the *amphora*. It is either cylindrical in form or egg-shaped, and always has two handles. The cylindrical amphora—Fig. 435—has a tall neck, on either side of which the handles rise from the shoulders to the head of the vase. Its base is generally a solid cone, for the purpose of fixing it in an upright position upon the deeply sanded floor of the storehouse in which it would be deposited. Amphoræ of the form represented in Fig. 436, are much less common than those of the cylindrical figure. These vessels of the long shape are represented upon Athenian and other Greek coins. Upon the silver tetradrachmæ of Athens, they appear lying horizontally with an owl perched upon them, and they probably allude to the Attic export trade in oil, which was shipped in these vases. Throughout Greece itself, and

Fig. 431.



Fig. 435.

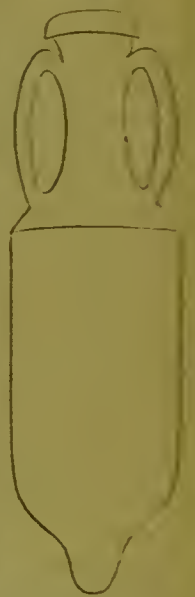


Fig. 436.

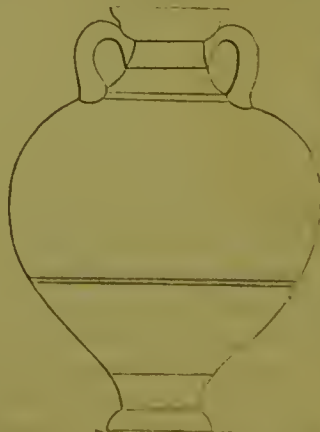
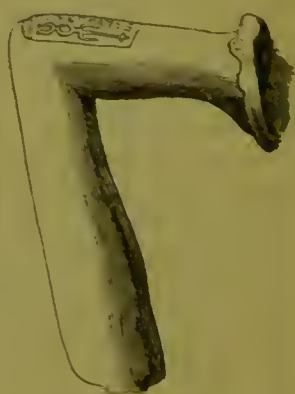


Fig. 437.



wherever Greek influence had ever extended, there the remains of amphoræ have been discovered. In many

instances the vessels themselves have been preserved; but the more prevalent relics are the handles, which are constantly found in great abundance when all other parts of the vessels have disappeared. These handles are either slightly curved, as in Fig. 435, or they rise perpendicularly from the body of the vase, and are attached to its head by horizontal shoulders, after the manner of Fig. 437. The handles are solid, and vary in height from about ten to twelve inches, the amphoræ varying from three to four feet. A peculiar interest attaches itself to these amphora handles, in consequence of their being generally impressed with a stamped inscription contained within a circular medallion, or an oblong, oval, or lozenge-shaped cartouche. These inscriptions record the names of local magistrates and merchants, with that of some month; and they sometimes are accompanied with a device typical of the place of their manufacture. Thus the Rhodian amphoræ are stamped with a head of Apollo surrounded with rays, or with a full-blown rose, which was the emblem of Rhodes so long as the island retained its independence, the Apollo Helios—the sun—being identical with the famous colossus. In many examples the medallion is found to have been stamped upon the body of the vase. The paste from which the amphoræ of Rhodes were formed, is singularly pure and tenacious. The color is pale externally, deepening within to a bright salmon hue. The clay of the Cnidian amphoræ is coarser than that of the Rhodian. In color it is darker and duller, and it breaks with a rugged instead of a sharp and clean fracture, displaying particles of a black micaceous sand. The composition of these vases exhibits other varieties in specimens fabricated in different localities, and the types apparent in the stamps comprehend various devices.

Greek vases in terra-cotta have been occasionally discovered, which were evidently designed for a diversity of uses. There is a vase of a pale clay in the British Museum that is covered with a coating of lime, and when found contained human bones; this is evidently a sepulchral vase. Several other vases, also

Fig. 438.



apparently sepulchral, have been discovered in Italy. Others again, from their forms and the style of their decorations, may be presumed to have been made for ornamental purposes. The most remarkable are those that have been modelled in the forms of the heads of BACCHANTES and other figures. This last class of

terra-cotta vases comprehends many curious specimens of the *rhyton*, a drinking goblet, modelled in the shape of animals' heads, Fig. 438, or having long reeded bodies, with *amphoræ* or jugs and other vessels ornamented with figures in high relief. Many of these objects have evidently been adapted, from works in metal, to the plastic materials that have survived the destruction of their metallic models. The tombs of Italy, and sometimes those of Greece, have been found to contain vases of simple terra-cotta, that had been substituted for the glazed ware more generally employed in the sepulchral rites then prevalent in those countries. Such vessels exhibit a great diversity, both in their sizes and forms and in their decorations. Color was freely introduced as a means for executing the decorations of terra-cotta vases of every class; modelling in relief, however, must be regarded as the system of ornamentation more generally prevalent.

GREEK GLAZED VASES in their general characteristics resemble those fabricated in unglazed terra-cotta, their own distinctive qualities consisting in their peculiar excellence as works of ceramic art, together with the glaze that is suffused over their surfaces. The paste or body of which these vases are composed is remarkably fine and light, tender in its texture and very porous, deeper in tone than the ordinary terra-cotta, and giving forth a metallic sound when struck. In different vases, however, which possess in the same degree all the other characteristic qualities of their class, the texture varies considerably, being sometimes so hard as scarcely to admit of being cut with a knife, while in other cases it is sufficiently soft to receive impressions from a finger-nail. Natural clays, selected from their fitness for the purposes required to be fulfilled by them, appear to have been almost exclusively used by the Greek potters; and, indeed, it is doubtful whether they ever introduced any foreign substances into their clays. As a matter of course they may have mixed together clays which, as their experience had taught them, were distinguished by contrary qualities, both before they were placed in the furnace and while exposed to the action of the fire; and thus pastes may have been obtained which were either more or less *fat* or *dry*, and might prove more readily fusible, or might be more refractory in resisting the influence of a high temperature. For the vases of the red ware it has been supposed that the paste received an admixture of oxide of iron; and certainly, in some of these specimens, the paste has been found to contain this metallic oxide somewhat largely. At the same time, it is most true that many clays are naturally impregnated with that substance. In the Greek vases of Campania the pastes have been proved to contain a considerable proportion of the oxide of iron, as is apparent from the following mean of eight analyses of this pottery, made by M. SALVETAT at Sévres:—

	Centesimally.
Silica,	55.88
Alumina,	18.88
Oxide of iron,	15.8
Lime,	7.48
Magnesia,	1.63
Loss,	0.33
	100.00

BRONGNIART gives the following as the mean result of his analyses of the paste of Italo-Greek vases:—

Silica,	55.49
Alumina,	19.21
Oxide of iron,	16.55
Carbonate of lime,	7.48
Magnesia,	1.76

The comparative results of several other analyses of this paste, show the wide range of the proportions assumed by the component elements in vases from different localities. In these analyses the silica varies from 55 to 32; the alumina from 24 to 15; the lime from 10 to 7; and the oxide of iron from 24 to 12.

The ordinary paste of Greek vases in other localities has a natural character, and is comparatively free from the presence of the metallic oxide.

In the paler pastes the proportion of the lime is increased. The ware has been found to fuse at 40° Wedgwood, and it certainly was exposed by the Greeks only to a low temperature. It is remarkably porous, allowing water to exude. Its extreme lightness was considered by the ancients one of its most important qualities. Certain sites in ancient times enjoyed a high reputation for their plastic clays. The excellent materials for their pottery, however, were found by the Greeks to have been distributed by nature through every region in which their artists practised their vocation.

The colors used by the artists who painted the glazed vases of the Greeks, were chiefly black, white, brown, yellow, and red; the last three being variously modified in their tone. These hues were protected, at the same time that their brilliancy was enhanced, by a fine thin glaze, which is both lustrous and transparent. The white and other hues used upon these vases are not enamels, but opaque clays, or *engobes*, painted, after sketches of the designs had been executed, upon the clay. In many specimens, from which the coloring has peeled off, the sketches exhibit an admirable freedom of hand, and the most spirited treatment. The glaze was spread over the entire external surface of the vases, except the under part of their bases, and then the vases were baked; and afterwards the painting was completed. The additional colors that were laid on after the firing, were also subjected to the action of the furnace, but at a comparatively low temperature. The white paint has been considered to have been a white alumina or pipe-clay, or a carbonate of lime; or a mixture of carbonate of lime and oxide of iron. The same oxide has been detected in the rich crimson of the oldest vases, and iron in another proportion in the lighter red. The yellow is an ochre. BRONGNIART, contrary to an opinion accepted by many persons, denies the presence of manganese in the black paint used by the Greek vase-painters, and attributes that important color to a metallic oxide. Various other theories exist with reference to the true nature of this black, which assumes different hues under different conditions. On the vases of Vulci, for example, it has a greenish hue. It often approaches a deep grey on the Campanian vases, while on those of Nola and Cære its blackness is rich and glossy, like that of polished jet.

The Greek glaze differs essentially from the lead and

tin enamels of Assyria, and the copper enamel of Egypt, since it is an alkaline silicate, containing a certain portion of oxide of iron. The black glaze employed in the Greek vases, especially those found in Campania, has been supposed to be, in great part, due to volcanic ashes spread by the brush over the parts required,, the vase being then exposed to the heat necessary for their fusion. The analysis of this Campanian glaze, according to SALVETAT, produces the following results:—

Silica,	45.27
Alumina,	11.49
Lime,	5.79
Soda,	17.10
Oxide of iron,	16.50
Loss,	2.99
100.00	

Except in the quantity of soda, this compound differs but little from some volcanic ashes. In other analyses of the black glaze, the results have given—

Silica,	63.00	or	55.49	and	55.88
Alumina,	20.00	"	19.21	"	18.88
Oxide of iron,	4.00	"	16.55	"	15.80
Carbonate of lime,	9.00	"	7.48	"	7.48
Magnesia,	2.00	"	1.27	"	1.63
Water,	2.00	"	—	"	—
Loss,	—	"	—	"	.73
100.00			100.00		100.00

In executing the subjects painted upon vases, the early practice, as exemplified in vases about seven hundred years before Christ, was to sketch the figures and patterns in red upon a reddish body, and then to color the composition with a black glaze, after which the vases were fired. Engobes of white and red were added in parts, and portions of the figures were picked out by incising through the glaze with a pointed instrument. Somewhat later the design was sketched in black instead of red. In other early examples the ground of the vases is of an ash-color, and the designs were executed in black, white, and red, with incised lines. In these vases the grounds were very commonly represented as being *semée* with flowers. To this class of vases there succeed those with black figures laid upon light grounds. They have the inner lines of the figures cut down to the ground of the vases with the graving-tool, and their accessories have been picked out in crimson or maroon color, and white. About four hundred years before Christ the vases attained to their highest degree of artistic perfection, when the figures and other objects appeared in red upon grounds covered with the black glaze, which had followed the contours of the several objects. In these vases, in place of the earlier incised lines, the inner lines were executed in black with the brush—a technical change which greatly facilitated the free and effective action of the artist. The subjects represented upon the vases of this period are such as may have been suggested by the contemporary works of the great painters, and by those also of the favorite authors of the day. They for the most part represent mythic scenes, genuine historical subjects unfortunately being rare. The sepulchral *lecythi* of the same period, and the *alabastra* or unguent vessels, were formed of a fine white clay covered with a white pigment, on which designs have been traced in black,

red, and brown. The progressive decline of Greek art after the time of ALEXANDER the Great, is very clearly indicated by examples of vases still in existence, and which are to be referred to that period of decadence. In their shapes the vases gradually became less and less elegant. The subjects introduced upon them lost their noble simplicity, and became confused and exaggerated. Modelling in relief was intermixed with the painted compositions. The figures that still were painted became indistinct in their outlines, and were often crowded with details carelessly designed, and accompanied with the most unsatisfactory efforts to accomplish perspective and the effect of distance. The designs in these later vases, whatever they may be, were drawn in red upon a black ground, the inner markings of the figures having been less carefully indicated than was invariably the case in earlier examples. Patches also of white and red have been introduced into the accessories, which effectually destroy the monochrome simplicity of the earlier paintings.

The true glory of the vases of the Greeks consists in the gracefulness and beauty of their shapes. It is in their application of form in art that the Greeks may justly claim to have excelled all other nations. Whatever the particular aim of the Greek potter, the plastic material under his command assumed a chaste simplicity or a dignified nobleness of form. Greek vases, accordingly, are to be studied not merely in consequence of their archaeological and artistic interest, but also as examples of the most masterly treatment of the ceramic art. In many instances, peculiarly adapted to the requirements of Greeks who lived in ancient Greece, these vases may have ceased to fulfil the requirements of an existing generation. While, therefore, the modern potter judiciously declines to produce mere servile imitations of even the noblest Grecian models, he finds in the humblest as well as the most important vases of the Greeks, subjects for careful and thoughtful study; and he learns from them by what means he may improve the practical application of his own art, without sacrificing its originality or perverting its usefulness. And when they proceeded to apply painting to their beautifully formed vases, the Greeks did more than increase their commercial value, and improve their appearance as objects of daily use. The vases thus were empowered to transmit to distant ages the traditions of the Greek schools of art; and they became an inexhaustible source for illustrating the mythology, the manners, customs, and literature of Greece.

At first sight it might be supposed that all the Greek vases hitherto discovered, however great their variety, and however large their numbers, were either directly or indirectly designed for the express purpose of taking a part in the sepulchral and monumental ceremonials

of the Greeks. Such an opinion might have been deduced from the circumstance that every known example has been obtained from some Greek sepulchre. But upon more mature reflection, in the great majority of instances these vases appear to have been used in many ways by the living, before they were consigned to the still more secure guardianship of the dead. It has been proved that vases that had been won as prizes in the public games, were afterwards placed in the victors' tombs. In scenes painted upon other vases obtained from sepulchral deposits, various kinds of vases are represented in use; and the very forms and adornments of many varieties can scarcely fail to be accepted as conclusively demonstrative of the purposes to which they had been applied, previous to their final consignment to the sepulchres.

At a very early period of Greek history, fictile vases were not employed to receive and preserve the ashes of the dead. The Etruscans, as is proved by their cemeteries, buried their dead; the bodies being laid upon couches in the sepulchral chambers, with their personal ornaments, their arms, furniture, and vases. After the heroic age, when cremation was generally prevalent amongst the Greeks, vases began to be used as receptacles of the ashes; but they also continued to be placed in the sepulchres for votive purposes, and as either memorials of the past or in imaginary association with the future. Amongst the Romans the custom prevailed of employing fictile vases in their religious rites, including such as were connected with the inter-

Fig. 439.



ment of the ashes or remains of their dead. For such purposes the finest vases of the Greeks were conveyed to Rome, where, after the libations had been duly performed, the vases themselves were broken, and the fragments—like the broken sword-blades in the Celtic barrows—deposited in the corners of the sepulchres.

The character of the sepulchres in which the vases have been found varies considerably in different localities of Greece, Italy, and Asia Minor. Thus, the places of interment in Greece itself are graves small in size, and sunk to the depth of several feet below the surface; while in Italy, sepulchral chambers and stone-built

tombs predominate. The chambers from which the largest and finest vases have been obtained, are excavations in the rocks, such as the Etruscan tomb at Veii, represented in Fig. 439. Others of the early tombs of Italy were tunnelled in the earth. In Southern Italy, and particularly in Campania, they are large chambers beneath the surface; or smaller tombs, formed of slabs of stone, somewhat after the manner of mediæval stone-coffins, contained both the remains of the dead, and the vases that were deposited with them. Fig. 440 represents a tomb of this description, which

FIG. 440.



has been partially uncovered. In both examples the ordinary arrangement of the vases is clearly shown. The later resting-places of the Roman soldiery and of the poorer classes of Roman citizens, made of tiles, were of the same shape. Other tombs of larger dimensions are also found, sometimes carefully constructed of hewn stones, while others are formed of rough and massive stonework. The human remains and the vases are very commonly accompanied with weapons, ornaments, and other relics, of bronze, iron, and the precious metals. It is by no means uncommon to discover a large number of vases in a single tomb; thus Sir WILLIAM HAMILTON has recorded having seen a sepulchre in the archiepiscopal garden at Polignano, in which the archbishop had himself found more than sixty vases, including several of the largest size and the utmost beauty. When discovered, the vases are found to be arranged about the human remains, piled up in corners, and hung around the inside of the tomb upon hooks, or nails, of bronze or iron. Very many have received some degree of injury; others are in a complete state of preservation. Some few still retain the rivets with which, having been broken, they had been mended in ancient times. The oldest express mention of these vases in Greek authors is made by the poet PINDAR, who flourished five hundred and twenty-five years before CHRIST. Those deposited in the Athenian graves are distinctly alluded to by ARISTOPHANES. Painted vases are mentioned

by ATHENÆUS, SÆTONTIUS, STRABO, and the later scholiast of THEOCRITUS. To determine the age of the oldest existing specimens with anything approaching to exact accuracy, is not possible. Some seem to be coeval with the first dawn of Hellenic civilization, and many have been made at the same period with the earliest fictile works of the Etruscans. Between Olympiads eighty-four and ninety—before CHRIST four hundred and forty-four and four hundred and four—glazed vases of great excellence were produced. During the succeeding half century, the art attained its highest perfection. The close of another fifty years brought with it unquestionable evidences of an ineipient decadence. ALEXANDER the Great introduced into Greece vases made of the precious metals, after which the finest varieties of fictile vases fell into disuse. Before the middle of the third century before CHRIST, PLUTARCH has represented metal vases to have been in common use at Sparta; and consequently, it may be inferred that pottery of every kind was becoming comparatively rare. During the first century before CHRIST, vases of earthenware were entirely superseded by works in metal; and in the time of AUGUSTUS they were regarded both as rarities and as objects of antiquarian curiosity. The best and most accurate chronological classification of Greek vases appears to be as follows:—

Period I.—Archaic Greek vases, four hundred and fifty years before CHRIST.

Period II.—Fine Greek vases, from four hundred and fifty to four hundred years before CHRIST.

Period III.—Finest Greek vases, from four hundred to three hundred and seventy-five years before CHRIST.

Period IV.—Greek vases of the decadence, from three hundred and seventy-five to two hundred and twenty-five years before CHRIST.

Period V.—Debased Greek vases, after two hundred and twenty years before CHRIST.

A second classification, which has reference to the uses of the vases and their nomenclature, must be determined by their sizes and shapes, and in some degree also by their artistic character. Amongst the most important, and also the most characteristic of the varieties which may be considered to have been satisfactorily identified, the *amphora* is the best known. In their general character, the painted and glazed amphoræ resemble those in terra-cotta—Fig. 435—but at the same time they admit several important modifications of the prevalent type. The painted amphoræ generally were provided with flat circular feet, as in the example represented in Fig. 436. The forms and arrangement of these feet vary in different specimens; and other variations of design and treatment are apparent in the forms and decorations of the handles, and in the contour and proportions of the vases themselves. The style and execution of their decorative accessories necessarily depend upon the period to which they may be assigned. The amphoræ include in their numbers the most admired and the most admirable of the vases of the Greeks.

The *pithos* is a jar, with a wide open mouth, of large size.

The *stamnos*, a jar used to contain wine and oil, has two small handles, and still retains its name in Greece.

Amongst other uses, the *hyrche*, a large species of amphora, served to hold the tickets on occasions when lots were drawn at Athens. The *Iagynos* is smaller, and has a long narrow neck. It was used at table by the Greeks, and is the vessel which the stork is represented in the fable to have set before the fox at dinner. The title *ascos* is applicable to several vases, which are more or less direct imitations of the *ascoi*, or wine-skins, commonly used in Greece.

The *calos* appears to be a globular vessel for containing fluids.

Fig. 441.

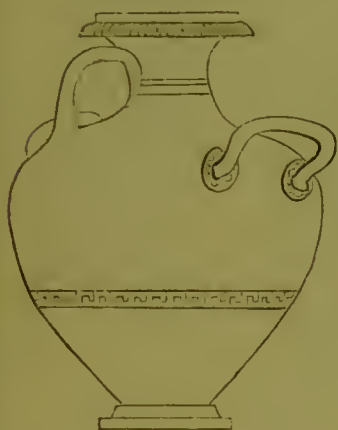


Fig. 442.

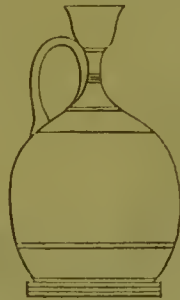


The *calpis*—Fig. 441—a water-vase, used also for unguents, and sometimes made to contain the lots of the judges, is principally found in the sepulchres of Southern Italy. It has three handles, like the *hydria*

Fig. 443.



Fig. 444.



—Fig. 442—which predominates at Vulci and other more Northern districts. The *hydria* is the older type, and it has been identified from the circumstance of the word *HYΔΡΙΑ* being inscribed over a vase of this shape in a vase-painting, representing *POLYXENA* going out from Troy to draw water from the fountain. In other painted scenes, *hydriæ* are represented on the heads of females who have been drawing water. These vases are generally black, and are ornamented with a frieze above the principal painting.

The *crossos*, a two-handled vase, was used in water-drawing.

The distinctive peculiarity of the *rhyton*—Fig. 438—consists in its form being such, that it could not be set down except when empty. It was made in the highest perfection in the time of *PTOLEMY PHILADELPHUS*, about three hundred years before *CHRIST*.

The *lecythus*—Fig. 443—or oil-cruet, found chiefly

in Greece and in Southern Italy, commences with the early vases having black figures, and terminates with the

Fig. 445.



best vases with red figures and white grounds. Another well-known vase, of a jug-like shape, and having a spout and a single handle, is the *anochoë*, which appears in the frieze of the Parthenon; the *olpe* is supposed to be a variety of this vase. Other varieties of it are the *prochoos*, the *aryballos*—Fig. 444—the *arystichos*, the *aryter*, and the *cotylos*. The *aryballos* is represented by Fig. 444, and the *cyathos* by Fig. 445.

The *crater*, a large open bowl with two handles, used as a wine-cooler, and found in Southern Italy, has various modifications, severally distinguished as the *holmos*, *oxybaphon*, *psycter*, and *celebe*. A stand, having a hollow reeded foot, upon which the crater was commonly placed, was called the *hypocraterion*. Various other vases of bowl-like forms, and adapted to a diversity of uses, are severally distinguished as the *chytra*, the *thermanter*, the *holcion*, and others.

Many vases, in addition to the *rhyton*, were made expressly to serve as drinking cups or *scyphi*. Of these *HOMER* mentions several varieties of unknown forms. The most celebrated vase of this class is the Tazza-shaped *cylix*—Fig. 446—which takes rank amongst the most beautifully formed of the Greek fictile works. The *cantharos* and the *carchesion*, also, were popular drinking vases, and the *phiale*, a flat and saucer-shaped vase, was almost exclusively used in religious ceremonies. In addition to those already specified, a numerous series of other names for their different vases has been transmitted to modern times in the literature of the Greeks.

The potters of Greece, like their predecessors in Egypt, used the wheel, which is mentioned in *HOMER*. The processes of modelling and moulding were also in constant use by them. To one or other of these two processes the Greek potter would have recourse at every period of his art, in order to enable him to produce the handles and certain other parts of his vases, together with such of their constructive and decorative accessories as he might desire to execute in relief. The invention of moulding, when once introduced, appears to have become generally prevalent, and to have been employed for the production of many of the smaller plastic works, in addition to the details and accessories of vases. When completed on the wheel, and after the modelled or moulded additions had been

incorporated with the bodies of the vases, the ware was partially dried, either in the sun or in a furnace, at a low temperature, and then the painting took place. When the glaze had been laid on as well as the paint, the vases were placed in the furnace and carefully

baked. The furnaces themselves are often represented in gems, and upon the vases which they produced. They appear to have been of a very simple character, closely resembling the tall ovens of the Egyptians—Fig. 430.

Fig. 446.



Amongst the Greeks themselves the vases of Athens were those which enjoyed the highest reputation. They have been found in great numbers in Athenian sepulchres, and many of the existing specimens are unquestionably

works of the very highest excellence. Some of the most admirably executed of the Athenian vases—Fig. 447—are without any decorative figures or patterns, but are simply painted black, and they rely for their

Fig. 447.



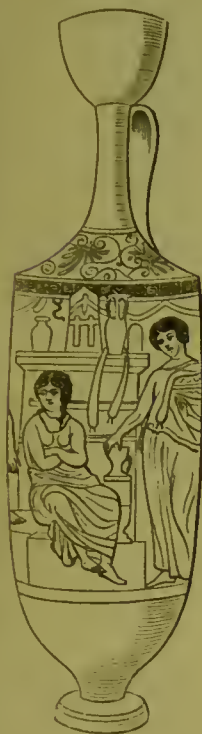
effect upon their beauty of form and the careful delicacy of their finish. Other examples exhibit a diversity of enrichments produced by the painter's art. Of these the Athenian lecythus, with a representation of ELECTRA and her attendants meeting ORESTES at the tomb of AGAMEMNON, is a characteristic specimen—Fig. 448.

The figures which are represented upon this vase will not fail to excite attention.

The neighboring isles both imported their vases from Athens, and produced other ceramic works of the same class themselves. In the other parts of the mainland of Greece vases are frequently found. Next to

Athens, Corinth has been the most productive; but, notwithstanding the ancient celebrity of the vases

Fig. 448.

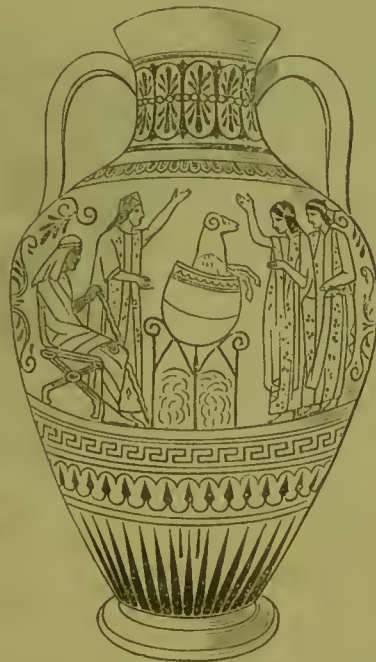


made in many of the Greek cities, a small number only of relics have been discovered on their sites. At Athens there were two pottery-quarters of the city, or *ceramici*—one within, and the other without the walls. Of the isles of Greece, Samos from the oldest times was the most renowned for its fictile wares. Samian pottery was always distinguished for its hardness, and for the fineness and the brilliancy of the red color of its paste. It maintained its reputation until the days of the Roman empire, when the island supplied services of its pottery to the imperial city. Melos and Ægina were also famous for the productions of their kilns. Passing eastward, the inquirer discovers remains of ancient pottery which convince him that, throughout the Greek settlements of the Lesser Asia, the ceramic art had flourished from the days of the earliest civilization. Such inferences are in exact accordance with the historical records preserved in the writings of antiquity. Thus PLINY has specified the qualities of extreme thinness and lightness as being characteristic of the vases of Erythræ in Ionia; and he adds that two amphoræ, peculiarly remarkable for those much esteemed qualities, the rival productions of a distinguished Erythræan potter and one of his pupils, were consecrated in a temple of that city; and the same writer has specially recorded the celebrity enjoyed in his times by the potteries of Tralles and Pergamos. These statements are corroborated by other ancient authors.

Whatever success may have attended the operations of the Greek potters in the various provinces of the Lesser Asia, they sink into insignificance when brought into comparison with the remains of Greek ceramic works that have been brought to light in Italy. On Italian soil, in ancient times, the ceramic art found a congenial home; and the Greeks who settled there worked in happy harmony with the Etruscan occupants of the country. The finest vases of pure Greek design and workmanship, and by far the greatest number of Greek vases of every class, have been discovered in Italy. Throughout Etruria, vases that are decidedly Greek in their characteristics of style and treatment, are continually discovered in close association with others in which Etruscan types are prevalent. It is highly probable that not a few of the Italo-Greek vases were imported into Italy from the potteries either of Athens or of some of the Greek isles; but at the same time it may be considered to be beyond all question certain that vast quantities of this beautiful ware were produced in Italy itself, by the Greeks who had settled

and become established there. The same general system of coloring is observed to have prevailed in all the vases of Italy, whether they are to be considered of Greek or of Etruscan origin: thus, the figures in the early Greco-Italian vases are black; but during the best period of Greek art, from the epoch of PHEIDIAS and POLYGNOTUS, before CHRIST four hundred and sixty, to before CHRIST four hundred, the figures are red upon a black ground. A curious and also an eminently characteristic example of the vases of the best Greek period is the *hydria* in the British Museum, Fig. 449, upon which is represented the device adopted by

Fig. 449.



MEDEA to induce the daughters of PELEUS to put to death their aged father. The ram, which had been restored to youth by the enchantress, is in the act of leaping from the *olla* or cauldron; he faces MEDEA. JASON is on the opposite side, and the other figures of the composition are behind these two principal actors in the scene. The design is painted in red on a black ground; the outlines are drawn in black, and the minor workings are faintly traced in red, with accessories in white and crimson. Another fine *hydria* of the same style and period, in which horses and bigæ are introduced with figures, is represented in Fig. 450. It was found at Vulci, and is preserved in the Museum of Practical Geology. In height it measures twenty-two inches.

In every district of Central and Southern Italy the active influence of Greek art is indicated by the presence of fictile remains, frequently of great excellence and in large numbers. The character of the vases, however, differs very considerably in different localities, and with rare exceptions they indicate some degree of artistic decadence. Here, as farther north, the productions of Greek settlers or works imported from Greece may be considered to be intermixed with relics in which local influences are more distinctly evident. The vases also, in almost every instance, are to be assigned to some period not earlier than the fourth

century before our era, many of them being about two centuries later. It is remarkable that after the arms of Rome had conquered Southern Italy, about the second century before CHRIST, the Greco-Italian settlements relapsed into utter barbarism. A progressive

decadence in art may be observed in the vase, as they approach more nearly to that era. Their forms are less graceful, the subjects show a painful deterioration in moral feeling, and the execution of the whole is comparatively coarse and degenerate. The Capuan vase

FIG. 450.



are among the most interesting relics that Campania has yielded to modern research. Those found at Nola are equally remarkable, and they comprise examples of all the principal classes, with a few local types. Their distinguishing characteristics are their smaller size, their peculiar elegance of form, and the exquisite beauty of their glaze, which is frequently an intense black. The figure subjects that adorn these vases comprehend many well-known mythic scenes and personages, together with incidents from private life or local history, which it is difficult, if not impossible, to explain. In the execution of these subjects, the figures are generally left in red, by painting with a rich and lustrous black glaze upon a red body or ground. The details of the figures are also sketched in with the same black glaze, and a little white is occasionally introduced. Figs. 451 and 452 show the forms and painted decorations of two beautiful Campanian vases that are in the Museum of Geology. Fig. 452 was found at Nola. Fig. 453, from the same collection, is a no less excellent example of a Campanian ribbed vase, of about two hundred years before CHRIST. It was turned on the lathe; the body is red and the glaze black. The ornament on the neck is in engobe over the glaze, and in part incised through the glaze. Among the shapes particularly local at Nola is a species of *uenochœ*, modelled in the form of a

head generally, but not always, that of a female. Vases of Nolan fabric are found distributed through-

Fig. 451.



out Campania. The vases of Paestum have pale red figures on a black ground, with a dull varnish. They

are of a late period, but singularly good as examples of the age to which they belong. Still further South, the region now called the *Basilicata* has pro-

Fig. 452.



duced an abundant store of vases, which illustrate in a significant manner the decadence of Greek art. Here and there specimens are found of such rich and superior character, that they are undoubtedly importations from Greece itself, and several styles or gradations of style may be observed in the genuine Basilican vases; but the prevailing characteristics of these vases, in addition to the general inferiority of their shapes, are clumsy forms and indistinct representations of figures, crowded with details, and accompanied with most unsatisfactory attempts to render objects in perspective. In these vases the design is drawn in red on a black ground, in the same manner with the examples of a purer period; but the drawing is bad, and the inner markings of the figures are carelessly indicated, and white and red patches are freely introduced into the accessories; the glaze also has a leaden hue. The subjects are generally Dionysiac and Erotic scenes, and they commonly are treated in a manner altogether inconsistent with that simplicity and dignity which are distinctive characteristics of the highest class of ceramic paintings. The vases found at Ruvo comprehend the finest works of their class that have been discovered in the Basilicata. The Museum of Geology supplies a characteristic specimen of a vase of Ruvo—Fig. 454. It is of an early period, about three hundred and fifty-seven years before CHRIST, and the execution is the same with

Fig. 453.



that employed in the production of the Campanian vases—Figs. 451 and 452. It is a singular circumstance that in Southern Italy the vases that are

Fig. 454.



discovered are far more frequently found broken into fragments, than in a condition that is even comparatively perfect. The ceramic works produced in Sicily, either by Greek settlers or under Greek influence, differ in no material points from the corresponding remains that are found in Italy; and the Greek vases that have at different times been brought to light along the African coast, with those more recently discovered in the Crimea, appear to have been importations from Athens, or from some other potteries of Greece.

ROMAN POTTERY.—Terra-cotta was used by the Romans from the earliest times of the republic, and also during the era of the kings, for the production of architectural details, accessories, and decorations, as well as for works of statuary. Capitals and bases of columns, corbels, the crests of cornices, the frames of windows and doors, spouts, bas-reliefs for friezes, and almost every variety of object that was employed in Roman architecture, were constantly executed in this material. The most ancient statues of the Romans, with the bas-reliefs and figure-decorations of their temples and other public edifices, were of terra-cotta; and they continued to be thus produced through the agency of the potter, until the extension of the Roman power into Greece disclosed to the conquerors other and still nobler means by which such works could be called into existence. It is worthy of special notice, however, that the introduction both of Greek sculpture, and of sculptors from Greece into Rome, did not supersede the demand for works of great importance executed in terra-cotta. Terra-cotta was also used by sculptors in marble and bronze for their models. A vast number of figures of diminutive size is found throughout the republic to have been made of the same material, and they extend until the middle period of the empire; they comprehend figures of every imaginable class, which were apparently used at the festival of the Sigillaria, or sometimes for other purposes. Having stated that it would be im-

possible to enumerate all the purposes to which the Romans applied terra-cotta, BIRCH observes that some of these are too remarkable to be passed over without special notice; and he proceeds to specify bee-hives, or amphoræ used for living bees, that were made by the Romans in terra-cotta, with cones that were heated and placed before other bee-hives in order to burn the butterflies and other insects which attacked the bees; money-boxes also; tesserae, or tickets of admission to the games; moulds from which spurious coins could be forged; toys of every kind; small altars for the sacrifices offered to the Lares; and cages in which dormice were fattened, in order to prepare them for the palates of Roman epicures.

Roman Terra-cotta Vases.—Like the Greeks, and also like the Egyptians before them, the Romans employed vessels of fictile manufacture for every possible purpose connected with their commerce, and with the ordinary requirements of daily life. Vases of terra-cotta were made by them in every variety of shape and size. Specimens of enormous dimensions and capacity were fabricated at all periods, and they were employed as well for storing up figs, honey, corn, oil, wine, and other commodities, as for their transport from place to place. The largest store or transport vases were called *dolia*, and sometimes *cadî*. Amphoræ, having bodies generally more globular than those of Greece, were in constant use for a variety of purposes amongst the Romans; and, like many other Roman fictile productions, they almost always have the name of the maker stamped upon them. The paste of these useful and much-used vessels is coarser than that employed by the Greeks; and it has been observed that until a late period vessels made of the same paste with the amphoræ were used for sepulchral purposes, sometimes as sarcophagi or urns for the reception of the ashes of the dead, and, in some instances, as cases in which more precious vases might be preserved. The vases used for sacrificial purposes, in like manner, were principally of terra-cotta; and so also were the cups and other vessels which, in the case of many classes of the Romans, sufficed for the purposes of the table. The names given by the Romans to their various vases are commonly of Greek origin. Some are Latin, and speak for themselves, and others, and these are not a few, are obscure as well in their distinctive signification as in their origin. As their general characteristic, the Roman potteries must be considered to have produced useful vases, and such as were well adapted to the requirements of life, but which can by no means be regarded as beautiful or fine, and therefore worthy of taking rank amongst works of art. The paste, except in the case of the coral red ware, is much coarser than that employed by the Greeks; but the processes of manufacture were the same, comprising the wheel and all the modifications of modelling, moulding, and stamping. The vessels of very large size, from the necessity of the case, were built upon framework. BROGNIART has classified the terra-cotta pottery of the Romans in the following four groups, distinguished by the color of the vessels:—1, Pale yellow paste, comprising the casks, jars, and amphoræ; 2, Dull red and reddish-brown,

including the pottery of the first century; 3, Grey or ash-colored, which comprehends all Roman pottery of a date later than the first century; and 4, Black, under which division are grouped the Gallo-Roman ware, and those of the provincial potteries. This appears to be the most satisfactory of the many systems that have been proposed for the classification of Roman pottery. In adopting it it will be necessary to observe, that the wares of the different classes are now commonly found together, and they consequently were employed simultaneously by the Romans themselves.

Besides the larger vessels of the yellow ware, there are some subdivisions of this class in which the paste is fine in quality, and of either a rosy or a very white hue, and sometimes intermixed with grains of quartz. The vases formed of this paste are small, and of a superior order as ceramic works. The largest and most comprehensive class of Roman pottery is the second, which comprises nearly all the vessels used for domestic purposes. This red ware varies in color from a pale salmon hue to a deep coral, and in quality from a coarse and gritty compound to a fine compact paste. Grains of quartz and mica are occasionally found intermingled with this paste. This ware is generally red externally, and without glaze; but not unfrequently it is covered with an engobe of white pipe-clay, or more rarely with a black coating, susceptible of a good polish from friction. A subdivision of this ware, which has been distinguished as *false Samian*, has the red paste covered with a thin coating of still brighter red, formed from sulphate of iron. The greater number of the vessels that were made of the Roman grey ware were such as would be used in cooking, and consequently would be exposed to the heat of the fire. There is a distinct class of productions of this color, which closely resembles the modern stoneware of Staffordshire; it is heavy and sonorous when struck. The black ware, which was chiefly used for the requirements of the table, is distinguished by the fineness of its paste, and the skill with which the vessels were made; its ornamentation is rude both in style and in execution.

Roman Terra-cotta Lamps, which are found in considerable numbers throughout the regions that once were comprehended within the wide range of the Roman empire, form one of the most interesting products of the Roman potter's art. The greater number are of a red ware; but many are of a pale yellow or white hue, while others are black. The paste also varies considerably in quality, though it very rarely is as fine as that used in the production of their lamps by the Greeks. In form, these lamps are either circular, with a projecting nozzle and a handle, or elliptical or shoe-shaped. Some were placed on stands, others were designed to be suspended, and others again were not intended to require any external appendages. Many specimens have more than one nozzle, and examples are occasionally found in which various capricious shapes have been substituted for those which conform to the established types. Lamps are first mentioned by the Athenian PHIEROCRATES, who was contemporary with ALEXANDER the Great; but all those lamps that have been discovered in modern times were

evidently made during the imperial age of Rome. They were manufactured from moulds, and variously ornamented with groups of figures, devices, and patterns. Had the Romans of the empire been gifted with a historical taste, their lamps would have contributed in no slight degree to the illustration, both of their personal memoirs and of their national history; but the lampmakers of those times knew well the frivolous character of the purchasers for whom they worked, and therefore they were content to decorate their productions with figures of popular divinities, demi-gods, and heroes, and with representations of incidents, fables, and ornaments such as would be sure to be in harmony

Fig. 455.



with the prevailing sentiments of the day. Among the most remarkable examples that have come down to us, are several lamps bearing the devices and monograms adopted by the early Christians, with which may be included one—Fig. 455—upon which is stamped in relief the golden candlestick of Israel, as it appears upon the arch of TITUS. After the Roman manner, in addition to their decorations, these lamps are generally inscribed with the names of the potters and potteries, or with the places where they were made, or with the

Fig. 456.



title of the class or style of the lamps themselves; while other inscriptions refer to the period of their production, or are of a votive character, or they are stamped with the word SAECVL, or SAECVLARIA—as Fig. 456—in reference to the games of the period.

Roman Red Lustrous Pottery.—This peculiar class of stitile productions, commonly known as *Samian* or *Aretine* ware from the celebrated potteries of Samos and Aretium, now Arezzo, in Tuscany, appears to have been in universal use wherever the Roman arms and the Roman name were known in the ancient world, numerous remains of it having been discovered in every

region in which the Roman people had settled after their conquests. The period of its manufacture is considered to extend from the first to the third century of this era; and it would appear to have been produced in large quantities, as well in Roman Gaul and Germany, as in Italy and at Samos. There is no evidence to show that the Samian was ever manufactured in this island, though its remains are sufficiently common, and especially at the more important Roman stations in Britain. It was apparently imported into this country, as it might have been into many other parts of the empire. The paste is of a rich sealing-wax red color, and well worked before it was wrought into vessels of various forms; BROGNIART, indeed, considers that it was worked in the most perfect manner, and with the aid of the greater part of the processes and means now employed in the most perfect manufacture. The vessels vary considerably in form, but are rarely of a large size. They are thin and delicate in their structure, and it may be inferred that they were considered valuable in ancient times from the fact of fragments being often discovered neatly riveted with lead. The red hue of the body or paste is derived from the sesquioxide of iron; and the brilliant glaze, which appears to have been formed of a silicate with an alkalino-earthly base, is colored red by the same means. Fragments of this ware have given the following analyses:—

	I.	II.	III.
Silica,	54.45	60.67	64.00
Alumina,	22.08	20.96	17.77
Sesquioxide of iron,	7.31	5.95	10.23
Lime,	9.76	6.77	4.86
Magnesia,	1.67	1.22	—
Water,	—	—	2.29
Potassa,	3.22	} alkalis in small quantities.	
Soda,	1.76		

The glaze has been found to consist of 64 silica, and 11.0 sesquioxide of iron. It is remarkable that this ware, wherever it may be discovered, is always exactly identical in its structure, forms, and style of ornamentation.

Across the centre of the bottoms of most Samian vessels are stamped the names of the potters, and they also appear upon the exterior surface of the embossed examples. The vessels themselves are either plain with mouldings, or they have delicate and fine patterns that have been appropriately designated *engine-turned*, or they are embossed with foliage and groups of figures. The scrolls, foliage, and other arabesques which appear on the Samian vessels very commonly, have a decidedly architectural character, and they rarely fail to demonstrate the sound taste of the artists employed in their production. A common form of Samian bowl, with characteristic arabesques moulded in relief, is shown in Fig. 457. The figure designs embrace an almost infinite series of curious and interesting representations of popular subjects which, like those introduced upon their terra-cotta lamps, are strikingly illustrative of the social and religious habits and customs of the Romans. Divinities and their emblems may be reckoned amongst these subjects, with priests and sacrificial ceremonies, bacchanalian processions

and dances, mythic and mythological scenes, fabulous and imaginary animals, other animals more true to nature, shows of gladiators, musicians, and others. The fragment in the British Museum, represented in Fig. 458, is in the highest degree characteristic of

Fig. 457.



Samian ornamentation; the figures are gladiators engaged in combat. Some few examples have the figures modelled in high relief, and affixed to the ware during the process of its production, instead of being moulded upon it. Moulds or materials used in pro-

Fig. 458.



ducing the embossed Samian have been occasionally discovered; they contain the designs impressed upon them in intaglio—as in the fragment—Fig. 459—found near Mayence—by means of a master-mould in relief. Specimens of such master-moulds have also been found:

Fig. 459.



and modelling tools, styles, punches, and other little instruments of ivory and bone, have lingered amidst the

remains of several ancient Samian potteries, as if for the express purpose of telling their tale to the inquiring explorers of modern times. This ware was evidently used much after the same manner that porcelain is at the present day. It is frequently mentioned by PLINY and other Roman writers, with whose words the existing relics are found to correspond with the most satisfactory precision.

Examples have been sometimes discovered in this country, and also in various other places, of glazed Roman pottery of a much paler red than the Samian, and altogether inferior to that celebrated ware. Other rare varieties are grey, yellow, brown, orange, or black: these wares sometimes have a lustrous glaze which shows the color of the paste, and in other examples the glaze has various hues of its own.

Roman Black Lustrous Pottery, made of any tenacious clay in the neighborhood of the manufacturer, varies in its color from a rich deep black to a slate or olive hue. The paste, in many instances, is red, grey, or even white; the black tint of the ware being due to the glaze, which is lustrous and has a metallized aspect. Many vessels of this class are of small size and simple in form, as in Fig. 460; others are ornamented with incised lines and herring-bone patterns, or with clusters of small studs; and it is also common to find them having their sides depressed in compartments, after the manner shown in Fig. 461. In this example, found in London, the sides are depressed in seven compartments, and there is also a small pattern produced by tool-marks in bands. Another mode of ornamentation exhibited in this ware

Fig. 460.

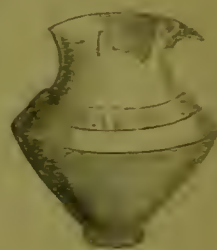


Fig. 461.



consists of scroll-work, foliage, and hunting scenes, with other figures, executed in low relief upon the vessels after they had left the lathe, by means either of a deposit of semifinid clay, which could be modelled, or by an engobe of white pipeclay. Vessels of this class, though not so generally diffused as the Samian, are found in considerable numbers in all the countries that once were subject to the Roman rule. In this island great quantities have been discovered, which exhibit some varieties of character. The most characteristic examples are from the neighborhood of Castor in Northamptonshire, where Roman kilns for their production also yet remain: this class of Roman pottery has accordingly obtained the title of *Castor ware*. The fragment represented in Fig. 462 is from Castor; and the vase—Fig. 463—which is a most characteristic example, was found at Water Newton, also in Northamptonshire. So perfect are the remains of the Roman kilns, that the different processes employed for firing the wares have been

accurately distinguished; and it has been ascertained that in the case of the black ware, the fire, or rather the smoke of the furnace, was smothered upon the

Fig. 462



Fig. 463.



vessels when in the kiln, and it is supposed that the carbon was thus deposited on the heated surfaces of the vessels, giving them their black glaze. It must be added that occasionally vases have been found which are identical with the black Castor ware, with the sole exception that in color they are of different shades of yellow and yellowish-grey.

CELTIC, ANGLO-SAXON, AND TEUTONIC POTTERY.

—The sepulchral mounds erected over the graves of deceased chieftains of the early European races, have contributed many examples of the vases that were fabricated, both before and after the era of the Roman dominion, in countries beyond the limits of Italy and Greece. The fictile works of the rude and primitive races who inhabited Western and Northern Europe in ages anterior to the spread of the Roman power, are precisely what might have been expected—simple, and, indeed, barbarous in their composition, their forms, their ornamentation, and manufacture. Nor does the civilizing influence of the imperial sway appear to have long survived the decline and fall of the empire; since the pottery which may be assigned to the centuries that immediately succeeded to the era of Roman occupation, exhibit scarcely any higher qualities than those of the primitive period. It is probable, however, that the ceramic relics exhumed from Anglo-Saxon tumuli, and from other sepulchral mounds of the same age, may represent but imperfectly the various kinds of pottery then in use, and particularly such as were employed for domestic purposes. The arts of the Romans, indeed, seem to have passed away almost with the receding steps of the legions; and, on the other hand, it is certain that much yet remains to be accomplished, before the manufactures of the Celtic and Teutonic races can be considered to have been thoroughly investigated. Urns and vases of various sizes and forms, generally without handles, and as commonly inverted as placed erect, are found in Anglo-Saxon tumuli; and, with objects evidently of British or Saxon design, others are occasionally observed which are no less certainly imitations of Roman works. The rudeness of the greater number of the specimens of Anglo-Saxon pottery, is indeed as remarkable as the tendency which it so generally exhibits to assimilate rather to the British than to the Roman types. The paste both of the Celtic and Saxon pottery is coarse, and consists of the clay found on the spot,

and without much preparation, and it has undergone a baking of only a very imperfect kind. The vessels are of a dull blackish-brown hue. They are generally of an urn shape, tapering towards the base, and having wide mouths with bevelled and overlapping lips; and their style of ornament consists for the most part of simple cords or bands of punctured zigzag and herring-bone work, intermixed with dots and small projecting bosses. The two vases represented in Fig. 464, exemplify, in a highly characteristic manner, this class of early pottery. Contemporary fictile works, found at the North of the Tweed, closely resemble the relics of the same class that have been exhumed from barrows in South Britain. The urns and vases discovered in Ireland are also closely analogous to the British; but they are frequently finer in their texture and color, more complex in shape, and more elaborate in ornament. Their general resemblance to basket-work

Fig. 464.



also is more distinct and decided than in the British specimens. In France the Roman dominion has almost obliterated any traces of the primitive Gallo-Celtic potteries, so that a very small number of rude relics of an ante-Roman period has been discovered; and but little more is at present known of the operations of the Gallic potteries during the centuries which succeeded to the Roman sway.

The Teutonic pottery, which is found throughout Germany, bears a considerable resemblance to that of the Anglo-Saxons. The urns are formed of a friable paste composed of clay and sand, intermixed with particles of mica, and the compound varies in color in different localities. Like the Celtic pottery, many of the smaller vases have been modelled by the hand; but some of these, and the greater number of the larger urns, bear decided marks of having been turned upon the wheel. Handles are not uncommon in these vessels. They are ornamented with incised and punctured patterns, or with small bosses, and their decorative accessories are also frequently produced by painting in various colors. In addition to sepulchral urns, vessels have been found in abundance throughout the whole of Germany, of such forms and sizes as denote their original application to various domestic uses. Some few of the smaller works are apparently toys; and others of larger dimensions and still more singular aspect, resemble the hut-shaped cinerary

urns of the ancient Etruscan inhabitants of Alba Longa, and were actually used for sepulchral purposes.

MEDIÆVAL POTTERY.—The manufacture of decorative pottery appears to have been unknown in Europe during that dark and stormy period which succeeded the fall of the Western Empire. Throughout these ages, however, there is every reason for believing that such simple fictile vessels as would be required for the ordinary domestic requirements of daily life, were produced by the different European nations. In process of time the potter's art reappeared in Spain, having been carried thither by the Mahommedans when they overthrew the Gothic monarchy in 711. But the influence of the Hispano-Moors did not extend beyond the region which had submitted to their arms, and, consequently, several centuries elapsed during which the ceramic productions of the rest of Europe knew no improvement. And when at last improvements began to be gradually introduced, earthen vessels still continued for a long space of time to be esteemed simply as articles of present utility, so that but few specimens have been preserved, and only casual notices of these objects have found their way into mediæval documents and records. It is known that the Arabs employed lead glaze in the ninth century, and that the Moors introduced their plumbiferous glaze into Spain early in the thirteenth century, about which time its use seems to have spread into other countries. Stanniferous glazes were also brought into Europe by the Hispano-Moors, and probably the use of both tin and lead in glazes or enamels became known in the West at about the same period, though the exact manner and time in which the knowledge of these glazes passed into the different European countries has yet to be determined.

Inlaid Tiles.—There is one class of the fictile productions of the middle ages which claims distinct and special notice. This class comprehends the various decorative tiles that were designed to form pavements, and in some instances to serve as surface-coverings of an ornamental character for walls. For England, in the thirteenth and three following centuries, paving-tiles were produced in great abundance, and in an almost infinite variety. The devices were obtained by impressing or incising the desired designs upon the slabs of dark colored clay, the intaglios being then filled in with a white composition; the surfaces were generally covered with a thick and lustrous glaze, but in some instances the terra-cotta was left without any such protection. The designs that have been observed upon these tiles comprehend geometrical and other patterns, miscellaneous devices, figures, architectural details, heraldry, and inscriptions, and they are invariably both curious and interesting. In some instances the designs are executed in low relief; and occasionally inlaid tiles have been observed that were produced for the purpose of monumental commemoration. A noble pavement of early tile-work has been preserved in the Chapter-house, Westminster; other examples of great excellence remain at Great Malvern, Gloucester, Worcester, and Ely Cathedrals, at St. Alban's Abbey, and in many other churches; but the very finest specimens are those which have very recently been discovered upon the site of Chertsey Abbey in Surrey.

Moulded terra, for architectural purposes, was also produced in great abundance and of excellent character in England, at the same period with the inlaid tiles.

SPANISH POTTERY.—Tiles of enamelled earthenware, called by the Spaniards *Azulejos*, were used for the pavement and the surface-decoration of their buildings by the Arabs wherever they extended their conquests. By the Spanish Moors these beautiful tiles were made in great abundance, and with those examples of them which yet remain, vases and other objects of decorative pottery may be associated. The Moors, indeed, appear to have continued their ceramic manufactures without intermission throughout their partial occupation of Spain, and until their final expulsion about the commencement of the seventeenth century. The colors introduced into the ornamentation of the Hispano-Moorish pottery are rich and gorgeous, abundantly intermixed with gold, yet always adjusted and blended together with judicious taste, and a thorough appreciation of harmony. The enamel is generally of a yellowish-white, over which an iridescent lustre plays with remarkable splendor. The designs and forms alike indicate their Oriental origin; the former comprise arabesques, scroll-work, flowers, and conventional foliage, with occasional birds and animals; and, in some examples, Spanish shields of arms and Arabic inscriptions. The patterns are infinitely diversified, and elaborate and intricate in the highest degree. Sometimes the Arabic legends appear on Gothic shields, and occasionally there may be seen instances of Christian devices and inscriptions. The tiles are formed of a pale clay, the surface being covered over with an opaque white enamel, upon which the elaborate designs are executed in colors. The celebrated fortress-palace of the Alhambra has supplied the most beautiful examples of the tiles—*azulejos*—of the Hispano-Moors, and also the most remarkable vase of their production that is known to be in existence. Other relics yet remain in different places where the Moors once were powerful: and the art of producing *azulejos*, learned by their ancestors from the Moors, is still practised by the Spaniards of the present day.

ITALIAN POTTERY.—Partly from the fictile productions of the Saracens or Moors, as the Arabs of Europe were called, and in part also from the ceramic manufactures of the Byzantine Greeks, Italy may be considered to have obtained the elementary principles of those processes which she cultivated with such distinguished success during the fifteenth and sixteenth centuries. As early as 527, the Saracens conquered Sicily, and adorned their great mosque at Palermo with colored and enamelled tiles, similar to those of the Alhambra. In this same ninth century the Saracens obtained a footing in Apulia. The island of Majorca somewhat later became a stronghold of the same invaders, and there they systematically carried on their characteristic ceramic manufactures with the utmost vigor. In the year 1115, the Saracen king of Majorca was defeated and slain by the Pisans, after a fierce and protracted struggle, when the Pisan galleys, amongst other spoils and booty, carried specimens of rich Moorish pottery in triumph to their native city. Fictile plates, known as *baccini*, are said to have been

incrusted in the walls of the churches of Pisa, as trophies commemorative of this event; and it is certain that the most ancient Pisan churches, as well as those of other parts of Italy, still retain examples of these *baccini*, which are apparently of Moorish origin. It will be remembered that the Moors themselves employed their enamelled tiles for the decoration of the walls of their edifices, and accordingly a similar treatment of the spoils of the conquered Majoreans would naturally suggest itself to the victorious Pisans; and thus the usage might prevail in Italy of incrusting the walls of churches with *baccini*-plates, discs, or pateræ of fictile ware. In addition to the spoils of the Majoreans, and the works of the Italo-Moors in Apulia, and of their brethren in Sicily, other fictile productions would appear at an early period in Italy in consequence of the gradual recovery of Spain from the Moorish invaders. The conquered Hispano-Moors would frequently settle in Italy, carrying with them their potters' art. So also, without doubt, the never absolutely lost art of the ancient potters would travel to the congenial soil of Italy from Byzantium, as soon as there would appear even a prospect of its receiving a cordial welcome. Indeed, in whatever degree the early mediæval potters of Italy may have been indebted to the Moors, and excited by their admiration for the brilliant prismatic coloring introduced into their fictile works by that remarkable people, the revival of the ceramic art in Italy must be considered to have also received a powerful impulse from the operations of the Byzantine Greeks.

In the thirteenth century Italian pottery claims to have attained to a distinctive character. The course of the succeeding century witnessed a progressive advance. Under the Malatestas, lords of Pesaro, the manufacture assumed a more decorative and artistic aspect, and the peculiar characteristics of the works of the two next centuries may be considered to have been determined. A new process at this period was developed, upon which the subsequent ceramic operations of Italy were based. The red, or other comparatively coarse and dark-colored clay which formed the paste or actual body of the pottery was first fired, or partly baked, and then, by immersion, it was covered with a thin coating or engobe of a composition formed of oxides of lead and tin, and of a very white earth procured from the territory of Siena; after this the ware was again placed in the kiln to receive its final firing. As the enamel was required to be more hard and white, the proportion of the tin was increased. The overlaying of an opaque white surface upon a colored body of a totally different texture formed a process altogether new, which may be regarded as the basis of the celebrated *Majolica* ware of Italy.

Born about the year 1400, and having his life prolonged until 1481, LUCA DELLA ROBBIA commenced his artistic career under LEONARDO, a goldsmith of Florence, of deservedly high reputation. He soon relinquished the profession of a goldsmith, and devoted himself, in the first instance, to sculpture in stone, and afterwards to modelling in clay. After many experiments, he arrived at the conclusion that an almost endless durability might be imparted to his figures in clay, by

overlaying them with a thick glaze of tin combined with other mineral substances. About the year 1438, LUCA succeeded in discovering an opaque white, highly lustrous stanniferous enamel, which he was the first Italian to apply to terra-cotta. His earliest works are in white on a blue ground; but he subsequently introduced green, maroon-color, yellow, and violet. He appears, however, to have used these colors very sparingly, and to have retained his preference for white and blue. The works of LUCA DELLA ROBBIA, distinguished invariably by their simplicity and purity of style, consist of Madonnas and Scripture subjects, with architectural ornaments and glazed tiles. LUCA was succeeded by his nephew, ANDREA DELLA ROBBIA, with the survivor of whose four sons the production of the Della-Robbia ware may be said to have passed away.

The remarkable class of ceramic productions known as *Majolica* is supposed to have derived its name from Majorea, where the Hispano-Moors had long practised the art of applying a peculiar lustrous enamel to pottery. It may be divided into the productions of four periods:—1. From about 1450 to 1530. The works of this period are distinguished as *Mezza Majolica*. In the earlier examples ornamental devices of a moresque character may commonly be seen, associated with busts and various Italian and mythological figures, and brief explanatory inscriptions. The figures represented upon the *Mezza Majolica* have their outlines traced in blue or black on a white ground, with faintly-tinted draperies: there are no shades or half tints, and the flesh is not colored: the drawing, though tolerably correct, is hard and harsh, and the figures have a flat and lifeless appearance. The whole is covered with a film of metallic glaze or *madre-perla*, that produces a richly-glowing iridescent lustre of a splendor that has never been surpassed. 2. The second period comprehends the ten years included within 1530 and 1540. At this era, instead of arabesque and foliage patterns, with busts and armorial bearings, the *Majolica* artists began to introduce groups of figures into their compositions; they made great improvements also in the art of coloring, and employed half-tints and full-colored draperies. 3. The third period of *Majolica*, in which the art was in its greatest perfection, extends from 1540 to 1560. 4. The fourth period, which extends throughout the decline of the art, may be considered to close about 1610, when true *Majolica* gradually ceased to exist; a species of imitative *Majolica*, however, continued to be made at Venice, Naples, Siena, and Savona, until the middle of the eighteenth century. After the year 1560 the decline of the true *Majolica* was rapid, having been in a great measure occasioned by the introduction of oriental porcelain into Italy. In addition to dishes, plates, and bowls of various sizes, the manufacturers produced statuettes, bas-reliefs, vases, candlesticks, inkstands, water-coolers, and cisterns also, and various other objects in *Majolica*. Artists of the highest celebrity were engaged to furnish designs for the decoration of this ware, and these designs were executed—many of them in relief—by men who might also claim to take rank with artists of no mean order. The engravings of MARC ANTONIO and the

drawings of RAFFAELLE and of his disciples were largely used by the Italian ceramic painters, and hence the Majolica has sometimes been denominated *Raffaelle ware*. The idea, however, that Raffaelle himself actually painted the Majolica is proved to be erroneous by the fact, that the finest specimens of the ware were not produced until twenty years after his death. In the sixteenth century classical, historical, and mythological subjects were introduced, and formed a strange medley with the paintings of Scripture subjects which still continued to be very prevalent. In the selection of these various subjects, the Majolica artists were in the habit of adopting those which might be considered peculiarly appropriate to their several works. Vessels to contain water, accordingly, were decorated with representations of such incidents as VENUS rising from the sea, or the catastrophe of PHARAOH. Fruit dishes were painted with vintage and other similar scenes. The actions of DAVID, SOLOMON, CÆSAR, or ALEXANDER, would be set forth on royal services; while those destined for ecclesiastical dignitaries would represent scenes in the lives of MOSES or Saint PAUL. It was a custom amongst the Italians to interchange presents of specimens of Majolica, which were always painted with subjects appropriate to the occasion. Of these, one class in great favor, called *Amatorii*, consisted of plates and vases, which cavaliers presented to ladies they admired. Portraits of the ladies, accompanied with their names and some complimentary epithet, were generally painted upon *amatorii*. From its first appearance, the Majolica received the most liberal encouragement from the Italian sovereigns. When the lordship of Pesaro passed in 1450 from the house of MALATESTA to that of SFORZA, the new rulers at once granted special privileges to the manufactories of Majolica. At Urbino, Majolica flourished under Dukes FEDERIGO and GUIDOBALDO, who severally reigned from 1444 to 1482, and from 1482 to 1538. Both of these princes were invested with the order of the Garter of England, the former in 1474, and the latter in 1503. To GUIDOBALDO, his sister's son, FRANCESCO MARIA DELLA ROVERE succeeded, under which energetic prince the ceramic productions of his country made rapid and most important advances. His son and successor, GUIDOBALDO II., who reigned from 1538 till 1674, witnessed both the crowning perfection and the incipient decline of the art, with which his name will ever be associated. The early *Mezza Majolica* was chiefly made at Pesaro. An artist, who flourished there about 1480, and who employed peculiarly brilliant ruby and golden yellow pigments, was the most remarkable ceramist of the period; his productions, readily distinguished by their peculiarities of treatment, as well as by their singular excellence, are always resplendent with the *madre-perla* glaze. The wares of Gubbio are also celebrated for their iridescent lustre; and the metallic glaze having a ruby color is peculiar to the productions of that city, in common with those of Pesaro. The great artist of Gubbio was MAESTRO GIORGIA ANDREOLI, the brilliancy of whose metallic colors is unrivalled. He delighted in the use of the ruby lustre; and, in addition to golden and silver lines of the same iridescent character, he introduced

an intermediate tint, which has the peculiar glow of burnished copper. It has been observed that the ruby lustre of this artist is transparent, and that when he desired to render it very deep and rich, he first placed blue beneath it. His pieces date from 1519 to 1537. The Majolica of Urbino comprehends a considerable portion of the specimens that still exist, and it ranges from the concluding quarter of the fifteenth century till the decline of the style had been far advanced. These works are in great variety, and they exhibit all the peculiarities, and also all the most excellent qualities of this remarkable class of ceramic productions. The most celebrated artists who painted the Majolica of Urbino were FRANCESCO XANTO AVELLI, whose works are not dated later than 1540, and ORAZIO FONTANA, the date of whose pieces is from 1540 to about 1560. The manufactories of Urbino also benefited by the services of several other artists of deservedly high reputation. Castel-Durante and Faenza are the other places most celebrated for their Majolica, which yet remain to be specified. But little is known respecting the artists who painted at these cities, but their productions may be grouped with the best Majolica of Urbino. Besides its Majolica, Faenza produced bas-reliefs, after the manner of LUCA DELLA ROBBIA; and this city, with Florence, was the first to adopt the beautiful white tin glaze, when the secret of its production had become known some years after the death of LUCA. The term *Fayence*, now generally applied to all enamelled earthenware, and particularly to that of Italy, is supposed to have been derived from Faenza, in commemoration of the early use at that city, in its ceramic works, of the white Della-Robbian glaze. In several cities of the papal states, Majolica was made during the best periods of the art; and subsequently, at the close of the sixteenth century and throughout the century following, and even later still, the same manufacture was actively carried on in several parts of Italy. The artistic character of the Majolica ware rarely fails to produce a powerful impression upon all who may have opportunities for observing it; at the same time, it is no less evident, that both the forms of the greater number of the pieces of this ware, and the nature of their decorations, are such as to render them objects, not of utility, but simply of decoration. In this respect the Majolica differs essentially from the finest vases of the Greeks, in which a useful application of the vessel always predominated over its artistic adornments. The Italian ceramic artists, on the contrary, treated their Majolica as a vehicle for the display of their paintings; and they, accordingly, aimed rather at the production of pictures upon clay, than at the decoration of the various useful productions of fictile art manufacture. It must be added, that Majolica was produced in the sixteenth century both in Germany and France. HIRSCHVÖGEL, an artist of Nuremberg, when travelling in Italy, visited Urbino in 1503; and, having there learned the art of making this ware, he established a manufactory in his native city on his return: his works are ornamented in relief. At Nevers in France also, a manufacture of Majolica was established by Duke LOUIS GONZAGA, about the year 1570, attempts having been already made to produce

the Italian ware at that city by CATHERINE de Medicis. That princess, herself a daughter of a Duke of Urbino, very naturally sought to introduce into France the characteristic production of her native country. It is remarkable that CATHERINE styled the Majolica *Fayence*. MARRYAT states, that it is difficult to distinguish the early works, produced under Duke LOUIS GONZAGA at Nevers, from the true Italian Majolica; and, indeed, it is probable, that the two classes of this ware may be almost identical.

FRENCH POTTERY.—In addition to the Majolica of Nevers, manufactories for the production of enamelled pottery existed at an early period in several cities of France. The ware of Beauvais was honorably distinguished as early as the twelfth century, and it continued to enjoy an increasing reputation during the four succeeding centuries. In the sixteenth and seventeenth centuries Avignon had ceramic works of some importance; and there were also other establishments of the same order in various parts of the South of France. Rouen possessed a manufactory founded by FRANCIS I., which in the seventeenth century was much celebrated. At the same period the productions of Nevers and of St. Cloud were held in high esteem. They were all enamelled, and they exhibit many qualities that still command admiration; but they were altogether deficient in that one quality—originality both in form and decoration—which in so eminent a degree distinguished the works that next claim attention. These are the Fayence of BERNARD PALISSY, who was born about 1500 at La Chapelle Biron, in Perigord. Of the humblest origin, this ardent, enterprising, resolute, and persevering man, whose history forms a genuine romance, rose to become an artist, an author, and a philosopher of the highest order. About the year 1550 PALISSY discovered the enamels which enabled him to execute the remarkable ceramic works that are identified with his name. He had labored through a memorable probation of fifteen years before success crowned his experiments. Thenceforward his career as an artist was one sustained triumph. He composed rustic pieces, or dishes, and other objects, ornamented with fishes, shells, plants, insects, and reptiles, all executed in high relief, and perfectly true to nature in both form and color. He modelled exclusively from the fish of the Seine, from the fossil shells of the Paris basin, and from other natural objects found in the same localities. His enamels are hard and brilliant, and his hues rich and vivid; but he did not discover the pure white of the early Majolica. He employed a tin glaze, upon which his colored enamels were laid. PALISSY made many large works for decorating fountains, *et cetera*, besides a vast series of smaller productions of every kind to which pottery is applicable. In the year 1589 this venerable and eminent artist fell a victim to the Huguenot persecution, and after his death his art speedily disappeared. His two brothers, or more probably his nephews, continued for some time to produce works somewhat in the manner of BERNARD PALISSY; but they were able to do no more than imitate at a distance the productions of their great relative.

The French *Fayence* of HENRY II., of the seven-

teenth century, is a class of ceramic works which comprises but a small number of pieces, and which flourished but for a short period. No particulars are known respecting either the artists who produced this Fayence, or the part of France in which they lived and worked. It is supposed, however, that the manufacture may have been carried on at Thouars in Touraine, and that the Fayence was the production of a single artist—probably an Italian, who had been in the first instance educated by some goldsmith of Florence. The period of this Fayence is determined by the presence of the insignia of FRANCIS I. upon the earlier specimens; while upon the later and more perfect works there appear the arms of HENRY II., with his device—the three crescents, or his initial H, interlaced with the two Ds of DIANA de Poitiers, Duchesse de Valentinois. The paste is a hard, fine, and very white pipe-clay, which did not require to be covered, like the Majolica, with any superficial coating. Upon this, when it had been modelled to the desired form, the decorative enrichments were incised, or perhaps in some instances impressed, the incisions or impressions being subsequently filled in with different coloring substances of yellow, brown, and carnation hues. The designs were drawn and executed with the utmost delicacy; and small detached figures, with various objects, designed after the *renaissance* feeling of the period, and boldly modelled in full relief, completed the ornamentation. Over the whole was laid a thin, transparent glaze of a pale yellow. The examples of this peculiar pottery may be compared to the *niellos* of the preceding century, with accessories of *repoussé* and chased metal work; and they contain some of the most delicate productions of fictile manufacture that are in existence.

GERMAN POTTERY.—Long before the introduction of the manufactory of Majolica into Nuremberg at the commencement of the sixteenth century, many parts of Germany had attained to a high degree of excellence in the practice of the potter's art. Throughout the Northern regions, the manufacture of fictile works was not limited to the production of portable vessels, but the use of moulded and glazed terra-cotta was extended to almost every variety of architectural work. Glazed tiles, also, of great size were produced in the German potteries, and particularly in those of Nuremberg. The German wares partake of the characteristics of Italian pottery in union with the artistic attributes of a Gothic race. The wares of a late period are generally of very elaborate workmanship. They are commonly ornamented with representations of the various animals of the country, and not unfrequently the different pieces are found to have been modelled in the forms of deer, bears, *et cetera*. Upon the Upper Rhine many potteries existed, which, in the beginning of the eighteenth century were converted into porcelain establishments. A fine enamelled ware was also made at Cologne, and colored enamelled wares were produced in Lower Saxony. Manufactories of a species of Majolica are said to have been established in various towns of Hungary, Transylvania, and Austria Proper.

DUTCH AND FLEMISH POTTERY.—Delft and the adjacent towns of Holland, were celebrated at an early

period for their fictile wares. These productions were imported into England as early as the reign of HENRY IV.; and, with other Dutch pottery, tiles remarkable for the beauty of both their color and their glaze were brought in great numbers into this country. Paving-tiles of green, yellow, and white, were imported from Flanders in the time of HENRY VIII. for Hampton Court, and for Christ Church, Oxford. Lord BACON introduced others of a similar character at his mansion of Gorhambury, near St. Albans. About the year 1625 these tiles became fashionable, and their use was very general in England. As the sixteenth century drew towards its close, the ceramic productions of Delft acquired a European celebrity, and the success which attended the manufacture of them may be pronounced unexampled. The objects themselves were for the most part closely copied, both in form and color, from the old porcelain of Japan, with which the Dutch were familiar long before it was known to the rest of Europe. The clay found in the vicinity of Maestricht was mixed with marl or sand; and this was covered with a beautiful glaze having a blue tinge, which presented a smooth and even surface, and received paintings, chiefly in blue, in imitation of the Oriental, without impairing the distinctness of the colors. One curious branch of the Delft manufacture consisted of dinner services, of which the dishes and covers were made in the forms, and painted to resemble animals, birds, and vegetables, such as are usually served at table. The pseudo-Japan Delft ware flourished until the commencement of the eighteenth century, when it began to decline. The superiority of the wares of WEDGWOOD caused the Delft to be superseded, even in Holland, by pottery of English production.

Stone-Ware—Grès Cérame—is a densely-baked earthenware, formed of clay mixed with sand, and glazed with salt. It exhibits, when broken, a close grey texture; it is somewhat vitreous, resists the action of fire, and is impermeable to liquids, even such as are of the most penetrating and corrosive nature. The stoneware of the Low Countries may be divided into common and fine. Both are commonly ornamented with subjects in relief, and colored; but the fine stoneware is distinguished by a more elaborate ornamentation as well as by the superior quality of its paste. The common stoneware appears to have been in general use towards the close of the sixteenth century. The specimens of it which are usually found in England consist of stone flasks, having a grotesque bearded mask on the neck, and some device on the body of the vessel. They are known as *greybeards* or *Bellarmines*, the latter name having been given to them in the reign of JAMES I., in derision of Cardinal BELLARMIN, and as an implied compliment to the king. The earliest examples of this ware are of a white-yellowish color, without any glaze, and delicately ornamented with Scriptural or allegorical subjects, produced in relief from copper moulds. This manufacture was indebted in a great measure for its early success to the attention bestowed upon the production of it by JACQUELINE, Countess of Hainault and Holland, the repudiated wife of HUMPHREY, Duke of Gloucester, after her abdication and

retirement in 1433. The later wares have a brown or reddish color, in place of the earlier yellow tint. The stoneware jugs of the same period have various ornaments in relief, including figures, armorial bearings, personal devices, with foliage and patterns, and also with dates and occasional brief inscriptions. Their enamel is hard, and of a rich brilliancy. The Flemish stoneware, or *Grès Flamand*, is peculiarly striking in appearance from its beautiful blue color—commonly used in combination with grey tints—its quaint forms, and rich ornaments. The manufacture of *Grès Flamand* extended from 1540 to 1620, when it gave way before the introduction of oriental porcelain.

ENGLISH POTTERY.—The few specimens of early pottery that have been found in England, and which may be considered to have been of home manufacture, are such as lead to the conclusion that before the seventeenth century this country was chiefly supplied with fictile productions from foreign establishments. In some few instances foreign workmen appear to have settled in England, and thus their art became naturalized with them. Vessels, most of them tall and slender jugs, have been discovered in excavations in London, which may be assigned to the fourteenth and fifteenth centuries, and were probably made in this country. Occasionally, also, other relics have been brought to light, the most curious being some terracotta models for stamping his wares, which had been used by a potter of the time of EDWARD III., and which were found, with numerous fragments, near the remains of a kiln at Lincoln. The glaze used was obtained from lead. Amongst the productions of the seventeenth century, an English Delft may be considered to have occupied a prominent position; dishes, plates, mugs, wine-pots, and other objects were made in considerable numbers at Lambeth, Fulham, Liverpool, and in Staffordshire, the process having been in the first instance introduced at those places by Dutch potters who had settled there. The wine-pots are globular in form, with narrow necks and handles; their color is white; and they are inscribed in blue with the words *sack*, *claret*, *whit*, usually accompanied by dates ranging from 1642 to 1659. A stoneware, identical in character with that of Flanders, was also produced in England in the reign of ELIZABETH, who made many efforts to establish potteries amongst her subjects; but little of importance, however, was accomplished until the close of the seventeenth century.

THE STAFFORDSHIRE POTTERIES, which now produce the great mass of the earthenware manufactured in this country, from their great local advantages have been intimately associated, from a remote period, with the art that has given to them their name. This district contains twelve lordships and three parishes, and now constitutes the borough of Stoke-upon-Trent. There the Romano-British ceramists plied their wheels and threw their clay. There the Saxon *tile-wrights* practised their useful calling, and transmitted to the Norman potters a hereditary craft. English potters now flourish in the same localities, and, in memory of long-past times, they still have amongst them a family named TELLWRIGHT—formerly written TYLWRIGHT—who for several centuries have been settled in Burslem.

and are in all probability descended from a remote ancestry who exercised what our Saxon forefathers—before the Normans had introduced the word *potta*—designated the *tile-wrights'* occupation. In the year 1686, Dr. ROBERT PLOT, in his Natural History of Staffordshire, first directed public attention to the potteries of that county. He mentions Burslem as being the seat of the most important pottery of the district, and he also speaks of the manufacture of tobacco-pipes at Newcastle-under-Lyne. He gives a minutely exact description of four varieties of white and red clays, all of them found within half a mile of Burslem, the best being dug up nearest the coal, which were of close texture and would work well on the wheel; and three other clays of looser and more friable natures, called *slips*, which were used for painting the wares. One considerable branch of the Burslem pottery manufactures at that time consisted of butter-pots—coarse cylindrical jars to contain butter for sale. An act of parliament passed in 1661, provided that these butter-pots should not exceed six pounds in weight, and should contain at least fourteen pounds of butter. Tygs or tiggs, drinking-cups, commonly having two or three handles, were made at Burslem, in addition to the butter-pots, both before and during the reign of ELIZABETH, and specimens of them are the earliest examples of Staffordshire pottery that are known to be in existence. The tyg was a kind of loving cup, and had its handles so arranged that two or more persons drinking out of it, and each holding a separate handle, might bring their lips to different parts of the rim. Ornamented dishes appear to have been made at Burslem as early as 1650. Until 1680, a lead glazing was employed; glazing by means of salt was accidentally discovered in that year, and first used by a potter named PALMER. About 1605, white and brown stonewares were made by THOMAS MILES of Skelton. These wares, when salt-glazed, were called *crouch-ware* by the Burslem manufacturers, who first produced them in 1690. The vapor arising from the salt-glazing is described as being so considerable, from about eight to twelve o'clock on Saturday mornings in the town of Burslem, as to produce a dense white cloud, sometimes so thick as to cause persons to run against each other in the street. At that period—1700—Burslem contained twenty-two ovens, each having eight mouths at equal distances. In 1852 it was estimated that upwards of sixty thousand persons were regularly employed in the hundred and thirty-three fictile establishments then in active operation in the Staffordshire potteries.

The first attempts that were made to imitate some Japan ware by the Staffordshire potters were not successful; but in 1690, two brothers named ELMERS from Nuremberg, discovered a bed of fine compact red clay, which enabled them to produce with complete success a fictitious Japan ware. The discovery of the use of calcined and pounded flint as an ingredient in pottery, attributed to the younger ASTBURY in 1720, led to great and highly important improvements in the Staffordshire wares. The new material was used in combination with pipeclay and sand, and colored with oxide of copper and manganese. The agate and tortoiseshell wares, some of the specimens being moulded

in relief and enriched with gilding, were thus produced. About this time moulds of plaster of Paris were introduced from France into England by RALPH DANIEL of Cobridge, and generally adopted by the English potters. The wares produced from these moulds were distinguished only by their different shades of color, and were known as drab, or cream-colored, and white. Printed and painted wares also soon followed the plain varieties. The forms and patterns of this pottery were generally obtained from the silver plate of the period. Such was the condition of the English pottery manufacture in the most important district in the country, when another PALISSY arose in England in the person of JOSIAH WEDGWOOD.

In common with several members of his family, THOMAS WEDGWOOD had carried on the manufacture of pottery for some years at Burslem, at the time of the birth of this son JOSIAH—the youngest of thirteen—in 1730. Very scanty was the education which the young JOSIAH was enabled to acquire, and very early in life he found it necessary to work as a thrower in his elder brother's pottery. His weak health compelled him to relinquish the more laborious occupations of his art, and to follow the natural inclination of his ingenious and enterprising mind. He made various ornamental and useful articles in clay, mixed with metallic oxides, and thus obtained imitations of jaspers, agates, and other variegated stones. In 1759 he succeeded in fabricating a white stoneware, and subsequently a cream-colored ware, by which he gained a high celebrity. This renowned ware was composed of the whitest clays of Devon and Dorset, mixed with ground flint, and covered with a brilliant vitreous glaze. It was capable of enduring sudden and violent changes of temperature, and was not affected by acids. Some specimens having been presented to Queen CHARLOTTE, WEDGWOOD was appointed the royal potter, and his cream-colored pottery he was desired thenceforth to designate *Queen's-ware*. His success having now become established, WEDGWOOD applied himself with the most devoted assiduity to the introduction of various improvements in the composition, glaze, and color of his productions. He consulted the writings of the best authors who had treated of chemistry; he worked assiduously at his own experiments; and he sought the aid and co-operation of the ablest workmen and the most accomplished artists. Having completed his most interesting discoveries, in 1763 WEDGWOOD opened a metropolitan establishment in St. James' Square, in connection with his friend BENTLEY, a descendant of the celebrated critic. Having obtained the loan of valuable specimens of antique sculpture, cameos, intaglios, seals, and other objects, WEDGWOOD produced the most admirable copies of them in his new wares. Amongst the most remarkable of his reproductions, are the fifty copies which he made in his peculiar pottery of the Barberini, now the Portland, vase. The Wedgwood Portland vases are examples of the *Jasper pottery* of this great artist. This remarkable class of fictile works was produced from a white body of extraordinary delicacy and beauty, which, unlike any other ceramic composition known either in ancient or modern times, possesses the property of receiving through its whole substance, from

the admixture of metallic oxides, the same colors that those oxides communicate to glass or enamel in fusion. The effect of this property was such as enabled WEDGWOOD to produce, in bas-relief, any figures or objects that he might desire, of the purest white upon colored grounds. The blue jasper of his grounds he obtained by adding to the mixture of his vitrescent materials oxide of cobalt, the quantity being increased as a greater depth of color was desired. In the case of the green jasper, the admixture was made with the protoxide of chrome. So great was the extent to which the manufacture of imitative gems was carried by this process, that the catalogue of *Antique Ornaments, et cetera*, published by WEDGWOOD in 1777, enumerates and describes seventeen hundred and thirty-five cameos, and three hundred and sixty-six intaglios, which had been reproduced by him in fac-simile from ancient works. Another important discovery made by WEDGWOOD, was that of painting on vases and other objects without the glossy appearance of ordinary paintings on earthenwares—an art practised by the ancient Etruscans, but which appears to have been lost since the days of PLINY. It is worthy of especial record that, in addition to his vast series of objects of an exclusively decorative character, WEDGWOOD also produced many articles of domestic use and requirement, all of them designed in the same true artistic spirit, modelled with the same care, and adorned with the same admirable bassi relievi, as his more elaborate and costly works. The fame of WEDGWOOD was so great that his works at Burslem, and subsequently at Etruria, a village created by him, and to which he removed in 1771, became a point of attraction to visitors from all parts of Europe; while his own talent and energy, coupled with the sound judgment which led him to secure the co-operation of such an artist as FLAXMAN, not only obtained for him extensive patronage and an ample fortune, but also greatly promoted the commercial interests, and exalted the reputation of his country. He died in his sixty-fifth year at Etruria, January 3, 1795. During his lifetime, WEDGWOOD sold his ware at a price which brought it within the means of general consumption, both at home and abroad; and so highly were his works prized on the continent of Europe, that, notwithstanding duties that were intended to prohibit the admission of British earthenware, not less than five-sixths of the entire quantity which he made were exported. His cameos and other works are still held in high honor abroad, and at home Wedgwood-ware of every description now finds ready purchasers at prices which significantly indicate its present reputation. It is most satisfactory to be able to add, that the influence of JOSIAH WEDGWOOD has acted most beneficially in promoting the permanent improvement of British pottery, and also that the wares which still issue from Etruria are not unworthy of their association with his name and his memory.

In the seventeenth and eighteenth centuries manufactories of pottery existed, and flourished with varying success, at Lambeth, Fulham, Liverpool and its neighborhood, Leeds, York, Bristol, Nottingham, Jackfield in Shropshire, and Lowestoff in Suffolk. The potteries of Lambeth and Fulham produced a species of delft

and a stoneware, with some excellent decorative tiles. At Lambeth the manufacture of stoneware is still carried on to a great extent; the materials are pipeclay from Dorsetshire, pulverized Staffordshire flint, and sand; a salt glaze is used, which renders the ware perfectly impermeable to water, and even to acids. The Liverpool manufactories produced many fictile works of considerable interest and importance. They are first mentioned in the year 1674. A century later, SADLER and GREEN introduced the art of printing upon pottery; and they succeeded so completely in keeping their process secret that, until the time of his death, WEDGWOOD was in the habit of sending his Queen's-ware to Liverpool to be decorated by the new style of ornamentation, after which it was returned to Burslem and Etruria. In 1752 RICHARD CHATTERS made a fine white earthenware at Liverpool: but finding WEDGWOOD a formidable rival, he directed his attention exclusively to the production of porcelain. After many disappointments, he succeeded in discovering accidentally the requisite materials, and he produced a chinaware of great excellence. About 1760 the manufactory of PENNINGTON at Liverpool became celebrated for punch-bowls and vases of delft. PENNINGTON was also noted for his wonderfully successful imitations of Oriental porcelain. He eventually broke up his Liverpool establishment, and retired to Worcester.

At the present day the potteries of Staffordshire and of other parts of England occupy a most important position amongst the national industries. Every imaginable object that may be produced from clay is now made by English ceramists, and the most elaborate and the simplest works are executed with equal facility and the same success. The early fictile productions of the country, *inlaid tiles* and *moulded architectural terra-cotta*, have been revived, and are now produced with admirable skill. His inlaid tiles were the productions which in a pre-eminent degree established the fame of HERBERT MINTON, a man whose name will ever be honorably remembered as one of the worthiest of ceramic art manufacturers. Messrs. MAW are more particularly distinguished for their tiles having geometrical designs, after the manner of the ancient tessellated pavements; and PULHAM of Broxbourne, in Hertfordshire, may be specified as taking the lead amongst the most successful producers of moulded terra-cotta.

MEXICAN AND SOUTH AMERICAN POTTERY.—Examples of several varieties of ancient pottery have been discovered in Mexico, and described by STEPHENS in his *Incidents of Travel*. They have been obtained from the ancient tombs of the country, and are remarkable for their singularly grotesque forms rather than for any other distinctive peculiarities; the fictile works of Mexico, however, at the time of the invasion by the Spaniards, are spoken of by the conquerors in terms of great admiration. The early pottery of Peru, Chili, and Columbia has a peculiar character which very decidedly distinguishes it from any European, and also from all Oriental works of the same class. It approximates to the Mexican, having the same uncouth and rude forms, and a similar grotesqueness pervading its ornamentation; and yet in connection with such indi-

ications of a rude condition of manufacture, many of these works exhibit in their carved or impressed decorations, patterns identical with such well-known classic forms as the Greek honeysuckle, the frette, and the Vitruvian-scroll. In his History of Brazil, alluding to the excellence of the South American potters, SOUTHIEY states that the Tupinambas were in many respects an improved race. The women were skilful potters, they dried their vessels in the sun, then inverted them, and covered them with dry bark to which they set fire, and thus baked them sufficiently. There were some who buried their dead in jars large enough to receive them erect. The Tupinambas, by means of some white liquid, glazed the inside of their vessels so well that it was said the potters in France could not do it better, but the outside was generally finished with less care. Fig. 465 represents a chief of the Coroados

Fig. 465.



Indians in his funeral jar, decked with his war ornaments and his arms, sitting on his heels in the usual posture of the savage in repose, and having some animal at his feet. Such sepulchral deposits are found at the foot of the large trees of the forests.

It is far from improbable that future researches may bring to light many varieties of pottery, some of them perhaps the simple and rude productions of aboriginal races, in regions which now can scarcely be said to have supplied any contributions to the history of fictile manufactures; and possibly, also, the sepulchres of long-departed generations may yet contain an abundant store of precious examples of ceramic art, scarcely less interesting than the most esteemed of those that are so well known, and which, at the same time, may prove to be distinguished by characteristic qualities peculiarly their own.

EUROPEAN PORCELAIN.—Although vases and other pieces of Chinese porcelain had found their way into Europe before the Portuguese doubled the Cape of Good Hope in 1497, it was not until after that event that this porcelain became well known to the various European nations. Having introduced comparative large quantities of Chinese porcelain into Europe about the year 1520, the Portuguese were succeeded in a great part of their East Indian traffic by the Dutch. The earliest known mention of China in England is in 1586. In 1600 the English East India Company was founded,

and having at length formed an establishment at Gambor in the Persian Gulf, it was enabled to introduce Chinese porcelain directly from that port into England, and hence it became known as Gamborware. In 1631 China was commonly imported into this country.

A familiarity with the porcelain that was brought into Europe from China, naturally induced a strong desire in the minds of European chemists and manufacturers, to produce a ware that was at once so beautiful and of such signal utility. Two centuries, however, had passed away before the most energetic efforts could attain to more than a habit of systematic copying of Chinese forms and patterns, upon the ordinary fictile wares of European production. The translucence that characterised and distinguished the porcelain of the East remained undiscovered until the commencement of the eighteenth century, when BÖTTCHER first succeeded in producing, at *Meissen*, the true porcelain known as *Dresden China*.

The two chief components of porcelain are entitled *Kaolin* and *pe-tun-tse*. The *Kaolin*—its name being considered to be derived from *Kaon-ling*, or *Lofty-ridge*, the name of a range of hills near the imperial Chinese porcelain works of *King-te-chin*—is an infusible substance, consisting of alumina or clay, or, in some cases of decomposed felspar; and the *pe-tun-tse*, or white paste, which is fusible, and produces the translucid quality of the ware, is composed of felspar or petrosilex reduced to powder. The two classes or varieties of porcelain, severally distinguished as *hard paste* and *soft paste*, contain the two principal ingredients in different proportions; the hard contains a greater quantity of alumina and less of silica; in the soft the proportion of silica is increased. The former acquires a greater, and the latter a less density. The latter, also, is soft in two senses; first, as being less able to resist a very high temperature; and, secondly, since the paste, where unprotected by the glaze, is easily scratched by an iron instrument. It must be added, that besides the naturally soft paste—*tendre naturelle*—there is a porcelain formed from a paste that is artificially soft—*tendre artificielle*.

BÖTTCHER was an apothecary's assistant of Berlin, who fled into Saxony to avoid the persecution which threatened him in consequence of his reputation as an alchemist. In 1709 he produced a true white porcelain of sufficient merit to induce the elector, AUGUSTUS II., to establish a manufactory. In the year following, BÖTTCHER was appointed director, and in 1715 he succeeded in making fine porcelain of great excellence. BÖTTCHER used the kaolin of Aue, in the *Erzgebirge*, and the most profound secrecy was rigidly enforced with respect to the entire process of the manufacture. Notwithstanding every precaution, however, certain workmen escaped from Meissen; and, the secret having thus become in some degree divulged, other porcelain manufacturers arose, one by one, in various parts of Germany, and particularly at *Höchst*, *Fürstenberg*, *Baden*, *Kronenburg*, *Nymphenburg*, and *Fromtrental*. In the year 1720 and 1751, the great establishments of Vienna and Berlin were severally founded, and they speedily obtained for their works the very highest

reputation. The porcelain of Berlin, indeed, rivals that of Dresden.

Meanwhile, in 1713, REAUMUR commenced a series of experiments, based upon the transmission of Chinese kaolin and pe-tun-tse to Paris by D'ENTRECOLLES, which paved the way for the successful use of those substances in the Sèvres manufactory, after they had eventually been discovered in France. Before this discovery, the researches of REAUMUR led to the production of an artificial porcelain from a soft paste—*pâte tendre*—the composition of which was both complicated and costly. Manufactories were established at *Chantilly* and *Vincennes* in 1735 and 1745; and in 1754 the manufacture was transferred, under a special royal sanction, to Sèvres. True kaolin was accidentally discovered in 1768, at *St. Yriex*, near Limoges; and having been ascertained by MACQNER to be both abundant and of good quality, it was introduced at Sèvres, where, in 1769, the production of hard porcelain was regularly established. The two varieties of porcelain, however, continued to be made conjointly at Sèvres until 1804, since which year the hard or true porcelain only has been produced. It is very remarkable that the quarries of *St. Yriex* produce not only the kaolin, but also the pure white felspar or pe-tun-tse which is indispensable in the production of porcelain.

Some degree of uncertainty hangs over the date of the first English porcelain manufactories at *Bow* and *Chelsea*, nor is it distinctly known what were the clays employed in the earlier works at *Derby* and *Worcester*. The natural kaolin of *Borey Tracey*, Devon, is said to have been worked in 1730; but the kaolin of Cornwall, which caused such great and important improvements in the porcelain manufactures of England, was not discovered by COOKWORTHY until about 1755. Kaolin, or *China-clay*, is now chiefly prepared from the granitic rocks of both Devon and Cornwall; and, as in the instance of *St. Yriex*, pe-tun-tse, called also *China-stone*, is obtained from the same Cornish rocks which also furnish the kaolin. Bone is an ingredient in common use in the composition of English porcelain.

In addition to the porcelain manufactories of Germany, France, and England, there are establishments for the production of this ware at *St. Petersburg* and *Moscow*, at *Amsterdam* and the *Hague*, at *Copenhagen*, at *Zurich* and *Nyon* in Switzerland, and in several cities and towns of Italy, Spain, and Portugal.

GERMAN PORCELAIN.—*Dresden* is remarkable for the beautiful forms, and the uncombined richness and delicacy of the painted and gilded decorations. Figures of every kind have been made in it at all times, and they are held in very high esteem. The Dresden candelabras have never been equalled by any others. The clock-cases and snuff-boxes, with the porcelain flowers, lace, and the honey-comb, and May-flower vases, are all of great beauty, and exemplify the singular taste and skill of the artists who produced them. The value of this ware is determined by the fashion of the piece and the execution of the paintings, which are generally copies of the works of the best Flemish and Dutch masters. The Dresden porcelain with the royal mark—two words crossed having a dot below them, A.D. 1778—is the most valuable.

Berlin porcelain, which closely resembles that of *Dresden*, is almost equal to it in form and painting. Berlin is now celebrated for the manufacture of a *lithophares*, or translucent pictures, executed in white porcelain. The porcelain of *Vienna* is thicker than that of *Dresden*, and its glazing has a grey line. It is distinguished by the excellence of its raised and gilded work, and for the application, in relief, of solid platinum and gold. It is now exported in large quantities to Turkey, Russia, and Italy. The *Höchst* porcelain, which was produced in no great quantities from 1740 till 1794, partakes of the beauty and excellence of the *Dresden* manufacture. In varying degrees, also, the same character may be assigned to all the porcelain produced in other parts of Germany.

FRENCH PORCELAIN.—In France the porcelain manufactures have always enjoyed the highest patronage, and every encouragement has been given to promote their success. The results have fully realized the most aspiring hopes of their friends and admirers. The early soft porcelain of Sèvres is remarkable for its creamy and pearly softness of color, the beauty of its painting, and the depth of its glaze. After repeated efforts the Sèvres artists, who have ever reckoned among their number men of the most distinguished ability, succeeded in producing upon the hard porcelain the most exquisite landscapes, with flowers, and various figures disposed in graceful medallions. Portraits and miniatures were subsequently introduced. The jewelled cups must be specified, as occupying a place of honor in the productions of Sèvres. In form this porcelain is decidedly inferior to the *Dresden*, but in beauty of painting, richness of gilding, and depth of color, it has never been surpassed. The peculiar ground-colors of the Sèvres porcelain, that so justly enjoy a pre-eminent popularity, are distinguished as *blue-de-roi*, a rich, deep blue; *bleu-turquoise*, a pale blue, the tint of the jewel; yellow, or *jonquille*, a full, glowing green, or *vert-pré*; and the lovely rose-color, called after Madame Dubarry, *rose-Dubarry*. In connection with the royal porcelain manufactory at Sèvres there is a *Ceramic Museum* of the utmost value and interest, the establishment of which was due to the exertions of the learned and accomplished director of the manufactory, the late M. BRONGNIART. Twenty-one other porcelain manufactories in France, besides that at Sèvres, are noticed by MARRYAT.

ENGLISH PORCELAIN.—About the middle of the eighteenth century the porcelain works of *Chelsea* attained to considerable importance, and under the patronage of GEORGE II., and of the Duke of CUMBERLAND, they produced services, and various pieces and objects of the very highest excellence. The early Chelsea-ware aimed at a close imitation of the Chinese, but subsequently the forms and decorations in favor in France were adopted, and retained in use until the close of the works about 1765. About the same period with the Chelsea, *Bow-china* was made at *Stratford-le-Bow*, and was generally distinguished by its embossed and quaint devices. When the Bow works were given up, about 1750, a porcelain manufactory was established at *Derby*, which, on the decline of the Chelsea-ware, became celebrated. It is very trans-

lucent, and of fine quality. This porcelain has long ceased to be produced; which is also the case with the beautiful ware, the first true porcelain of hard paste made in England, at *Plymouth*, by COOKWORTHY, and with the *Bristol*-ware, of still superior character, which succeeded it.

In 1751 the manufacture of porcelain was introduced by Dr. WALL, at *Worcester*, and, from the first, the works produced at that city have commanded decided admiration, and secured extensive patronage. The earliest efforts were directed to the imitation of the porcelain of China and Japan. About 1756 the important process of *transfer printing* was discovered and adopted at Worcester. In 1786 GEORGE III. paid a visit to Worcester, when he granted the patent which gave to that city the first *Royal Porcelain Works* in England. At this period, and until the present century had seen its first quarter pass away, the artists of the Worcester establishment appear to have been influenced by an irresistible desire to imitate the most attractive works of other ceramists, and they accordingly studied with equal attention the best productions of Dresden, Berlin, and Sèvres, as well as those of the East. More recently the Worcester porcelain, which has always been celebrated for its beautiful translucency, and the rich variety of its colored and gilded decorations, has gradually assumed a decided and definite character, and it stands in the front rank of the fictile manufactures of England. The present productions of the Worcester works comprise the most exquisite works of ceramic art, together with every variety of useful object—the spirited proprietors are Messrs. KERR and BINNES. Nearly contemporaneous with the works at Worcester are those that still flourish on the right bank of the Severn, at *Coalport* and *Colebrook Dale*, and other places in the same neighborhood in Shropshire, and produce vast quantities of excellent porcelain. The porcelain wares of *Nantgarrow* and *Swansea*, also of about the same date, were amongst the first that succeeded in England in attaining to the highest qualities of the manufacture; and besides these, attempts, attended with various degrees of success, were made in other parts of England, for producing the universally-admired porcelain for which Europe was indebted to the East. At the present day porcelain manufactories, side by side with those for the production of the humbler classes of fictile works in terracotta, are carried on in many parts of England, but Staffordshire and the city of Worcester still continue to be the scenes of the most important operations. Amongst the most distinguished of the Staffordshire manufacturers are the firms of COPELAND, MINTON, and RIDGWAY; and with them the names of ROSE and of BATES must be associated as ceramic manufacturers of the first class.

STATUARY PORCELAIN AND PARIAN.—Under these titles are comprehended some of the most beautiful and most popular productions of modern ceramic art. These delicate compounds were introduced about 1842 by COPELAND, MINTON, and KERR, for the execution of statuettes and other decorative works of a high order; and they have been constantly improved, until they now have attained to the utmost perfection. Delicate and

refined in the highest degree, the Parian or statuary porcelain is eminently sculptural in its aspect and tone of color, and at the same time it excites no suspicion of fragility or evanescence. Works thus executed are true works of art, and the comparative facility with which they may be produced renders them easy of general access.

CERAMIC ENAMELS.—The process for the application of enamels to metals, so famous in the middle ages, have been received by modern ceramists, and by them used for the decoration of certain classes of their own works. These works are executed on porcelain in the style of the *champlevé* metallic enamels of Limoges, but without their thread-like lines of gold; they exhibit the same beautiful tints with the enamels of the thirteenth and fourteenth centuries, and are uniformly distinguished by an exquisite delicacy of touch and general treatment, associated with admirable energy and decision of expression.

Turning from this historical account of the ceramic art to the modern practice of manufacturing the various kinds of pottery wares, the first thing to be considered is the nature of the *clays* and other substances used in the art of

PRACTICAL POTTING.—Clay consists of a hydrated silicate of alumina in combination more or less with other substances derived from the felspathic rocks, which by their disintegration and decomposition have formed the clay; the silicates of potassa and soda, which form constituents of the felspar, having been dissolved out by water during the decay of the rocks. The chemical formula of the more important varieties of clay, according to BROGNIART and others, may be represented by $2 \text{Al}_2\text{O}_3$, 3SiO_2 , 4HO , which appears to be the composition of the fire-clay of the Staffordshire coal measures. In nature, however, the greater number of clays is intermingled with substances foreign to them in their original localities, fragments of undecomposed rock, carbonate of lime, magnesia, and the oxides of iron, certain proportions of potash, and variable amounts of silica in the hydrated condition, all of which modify the character of the clay and its applications, according as one or other of these ingredients predominates.

Pure clay is soft, more or less unctuous to the touch, white and opaque, and when breathed upon emits a characteristic odor; it may be converted by water into a doughy, tenacious, plastic paste, insoluble in water. The most prominent physical properties of clay are its plasticity and behavior when exposed to heat; when slowly dried and exposed to a high temperature, it shrinks considerably, and splits into masses extremely hard, and does not undergo fusion in the furnace; the stronger the heat to which it is exposed, the more dense, sonorous, and hard the clay becomes, although still porous enough to absorb water with avidity. It is, however, a remarkable fact, that while an increase of temperature brings the pores of the clay continually closer together, and the burnt clay increases in density and in hardness, this is not the case with the mass itself—a fact which has been proved by weighing porcelain clay after it has been dried or burnt. Thus, porcelain clay which had been exposed successively to

different temperatures was found to vary in specific weight as follows:—

Temperature of	212°.	334°.	630°.	Cherry red heat.	Lively red heat.	White Heat.	
						Low.	Intense
The cubic inch weighed in powder in grammes	38.58	39.52	40.61	42.17	41.24	39.05	38.74

by which it will be seen that the density of the mass itself attains its maximum at an incipient red heat, and is reduced at a white heat to the same state which it had acquired at 212°. In the commencement the clay loses water as much as 8½ per cent.; after having been dried at 334°, this weight then remains unalterable. But other changes occur at a red heat; the particles of clay are augmented in volume and possess less density; at the same time, however, the interstitial spaces are diminished, and they approach more closely together, giving an increase of density to the whole mass of burnt clay, which is practically observed by a diminution of surface, and technically called the *shrinking* of the clay. It can easily be conceived that this shrinking will be very materially modified and affected by the admixture and proportion of foreign matters possessing other properties—substances which may either be constituted of undecomposed detritus of the rocks which form the basis of the clay, or of others which do not yield clay by decomposition.

Pure clay does not fuse in the most powerful blast-furnaces; it dissolves with difficulty in borax, producing a transparent glass; with carbonate of soda it forms a green glass; if ignited with solution of cobalt, it assumes a blue color. Clay is insoluble either by nitric acid or dilute hydrochloric acid; but boiled with diluted sulphuric acid until the acid begins to evaporate, the alumina is dissolved out, together with a small quantity of silica. By boiling in a solution of carbonate of soda, the quartz, sand, felspar, *et cetera*, frequently mixed with the clay, may be separated. The presence of clay in any soil may be readily distinguished by the absorbent quality which it exhibits; when applied to the tongue or lips in a dry state, it adheres to them strongly, absorbing the saliva from their surface. It is this absorbent property in clay which causes it to retain ammonia in the soil. The ingredients which most affect the character of clay are sand, iron, lime, and magnesia, and its plasticity diminishes in proportion to the amount of any one of these sub-

stances which it contains, as they are not plastic. Sand exercises the most marked effect in this manner; lime somewhat less, and oxide of iron very little. Clay containing sand is said to be *poor*, in contradistinction to *fat* clay.

When clay containing lime or iron is subjected to the action of heat, the silica, alumina, lime, and iron form together a mixture similar to that employed in the manufacture of bottle-glass, melting in the fire with more or less ease, according as it contains much or little of the latter two ingredients. Magnesia exercises less influence upon the character of clay; and the greater the amount of quartz and silica that enter into the composition of the clay, the more difficult it will be of fusion. Clays which contain an excess of iron or lime can be corrected by a large quantity of these ingredients. The fixed or *fireproof* clays are thus distinguished from the *fusible* ones. Those containing iron are either red, yellow, or blue, after firing, according to the quantity of the metallic oxide they contain, and the degree of heat to which they have been subjected. Many kinds of clay are permeated by an organic substance which gives them a blue, bluish-grey, or black color, arising from the presence of coloring matters which are of no practical importance, as the clay when exposed to the influence of fire becomes white.

It is upon the property which clay possesses of being converted by heat into a firm compact mass, no longer influenced by the action of water, that its employment in the preparation of bricks and vessels of various kinds depends; and with a view to this object the different varieties of clay have been classified into *fireproof*, *fusible*, *calcareous*, and *ferruginous*—the calcareous being those which effervesce considerably with acids from containing a large proportion of earthy carbonates, particularly lime, while the ochry or ferruginous clays contain much oxide of iron, and possess a red-brown color.

FIREPROOF CLAYS.—*Kaolin* or *Porcelain earth* is one of the most important materials in the production of porcelain. It is an earthy, pure white, greyish, or milk-white substance, easily pulverized. It occurs in granitic soils rich in felspar, but containing little mica or porphyry. The chief localities of this substance are Sedlitz, near Meissen; Morl, near Halle; Obernzell and Diendorf, near Passau; Saint Yrieux, near Limoges, Department Nièvre; Saint Austel in Cornwall; China and Japan. Kaolin burns perfectly white. The subjoined analyses exhibit its composition:—

	Kaolin from					St. Yrieux.	Auc.	Passau.	Halle.	St. Tropez.
	St. Yrieux.	Auc.	Passau.	Halle.	St. Tropez.					
	Berthler.	Kuhn.	Fuchs.	Bley.						
Silica,	47.09	47.64	43.65	39.62	55.80	....	....	....	....	....
Alumina,	36.41	35.97	35.93	45.00	26.00	....	....	....	....	....
Potassa,	1.56	—	—	—	8.20	....	....	....	....	....
Magnesia,	2.94	—	—	3.32	0.50	....	....	....	....	....
Lime,	—	1.57	0.88	0.07	—	....	....	....	....	....
Oxide of iron,	—	—	1.00	—	1.80	....	....	....	....	....
Oxide of manganese,	—	—	—	0.19	—	....	....	....	....	....
Water,	12.00	13.18	18.50	10.00	7.20	....	....	....	....	....
Loss,	—	1.64	0.04	1.80	0.50	....	....	....	....	....
	100.00	100.00	100.00	100.00	100.00					

Granite or *Cornish-stone* is a material also much used in the English potteries, and is brought from Cornwall, where the granite hills are intersected by extensive deposits of this stone. It consists chiefly of quartz and felspar, mica not being entirely absent. This rock—pegmatite—after exposure to the decomposing action of the weather for some time, is one of the chief sources, especially in Cornwall, of the porcelain earth. In Cornish stone, which is brought with the porcelain earth into commerce, the decomposition of the felspar has only proceeded so far as to render the stone easily pulverizable. It consists of kaolin, undecomposed felspar, and quartz.

Dr. LYON PLAYFAIR has made the following analyses of two specimens of kaolin from Bluebarrow, and from Saint Stephens, Cornwall:—

	Bluebarrow.		Saint Stephens.
Silica,	45.52	....	46.38
Alumina, with trace of oxide of iron,	40.76	....	38.60
Lime,	2.17	....	3.47
Potassa, with trace of soda,	1.90	....	1.77
Magnesia, phosphoric acid, and sulphuric acid,	traces	....	traces
Water, with a small quantity of organic matter,	9.61	....	9.08

The China Clay Works at Saint Stephens, Cornwall, are composed of extensive tracts of felspathic rock in a high state of decomposition, twenty feet thick, standing on a declivity. Trenches are formed around spaces of the rock, and strong currents of water directed into them, which carry off the decomposed portion, united with small micaceous particles. These streams are directed into large pits, termed *mica pits*, where the particles are deposited. The pits are fitted with boards, which are raised from time to time as required, and as the mica rises in the pit, the finer particles of clay being held in suspension flow over the boards, and are conveyed by channels into other and deeper reservoirs or tanks of very large dimensions. When these large reservoirs are filled, the washing process is stopped, and the fine clay is allowed to settle, and is removed in the state of slip or thin paste to more shallow drying tanks, surrounding the general reservoir. The latter are about eighteen inches deep, and in these the slip is allowed to remain until it becomes a stiff paste. Cutting tools are then passed through crosswise, and the superfluous water runs off. The mass is afterwards cut into squares, which are placed to dry on a space appropriated for the purpose, and previously sanded to prevent the squares of clay being mixed with extraneous matter. The squares are arranged in the most convenient manner for drying, and sand is

sifted over them. When in a sufficiently hard state, women are employed with sharp triangular scrapers, to remove all the sand with care, and the squares are then ready for shipment. The scrapings are collected, and again passed through the washing process, so that little or no loss of materials can arise.

The clays vary much in quality, some being much more aluminous than others, and, although not so white, yet possessing most valuable qualities, and making very sound wares. Beneath the argillaceous strata lie the Cornish stone, which is harder in texture, and can be quarried in masses ready for shipment.

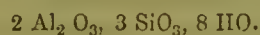
The clays are generally known by certain marks impressed upon them by the clay merchants, and which serve as a guide to the potters to recognize the several qualities, and adapt them to the uses of their manufacture.

Granite or Cornish-stone clay, previously dried at 212°, was found to consist of—

	1.	2.	3.
Silica,	46.32	46.29	35.65
Alumina,	39.74	40.09	32.50
Protoxide of iron, .....	.27	.27	1.65
Lime, .....	.36	.50	traces
Magnesia, .....	.44	—	
Water and some alkali,	12.67	12.67	30.05
Loss,	0.20	0.18	0.15
	100.00	100.00	100.00

Specimen, No. 3, was analyzed by RICHARDSON in its unprepared state.

Another substance, nearly allied to kaolin, and which occurs in large quantities at Houscha, near Bayonne, and is often used in the manufacture of porcelain, has been found by BERTHIER to be halloylite, mixed with a product of the decomposition of pegmatite; it forms a connected, tolerably soft, and easily pulverized mass, is of a dull white color and opaque, affording no dough with water, and consequently not plastic. BERTHIER found it, on analysis, to be represented by the formula—



Pipe-clay is of different colors, very tough, exceedingly plastic, and becomes white, or sometimes yellow in the fire, from the presence of a small quantity of iron. It is used in the manufacture of stoneware, clay pipes, earthenware, *et cetera*, and occurs in very considerable quantities. The most generally known localities are on the Lower Rhine; at Cologne and Coblenz, near Halle; in Devonshire and at Stourbridge in England; and at Dreux and Forges-les-Eaux in France. The following analyses show that these clays contain but little iron and foreign earths:—

	Grossalmerode. Forchhammer.	Strasburg. Berthier.	Stourbridge. Berthier.	Stourbridge. Editor.	Forges-les-Eaux. Berthier.	Coteau de Prairie, N. America, Catlin.
Silica,	15.906	66.70	63.70	62.99	52.00	48.20
Alumina,	11.170	18.20	20.70	20.04	27.00	28.20
Lime,	3.504	—	—	0.30	—	2.60
Magnesia,	—	0.60	—	0.94	—	6.00
Potassa,	0.786	—	—	—	—	—
Water,	4.119	12.00	10.00	10.70	19.00	—
Oxide of iron,	—	1.60	4.50	trace	2.00	5.00
Oxide of manganese,	—	—	—	—	—	0.60
Residue,	64.030	—	—	—	—	—
Loss, &c.,	0.485	0.90	1.10	5.03	—	10.00
	100.00	100.00	100.00	100.00	100.00	100.00

These analyses, however, give no clue to the nature of the aluminous compound. The proportion of silica in combination with the alumina and the proportion left free not being stated, while the amount of residue not capable of decomposition by the aid of sulphuric acid is only given in one instance, hence the great differences in the relative proportion of the alumina to the silica, which, observing the same order, is as follows:

3 : 1, 4 : 1, 3 : 1, 2 : 1, 1 : 1, and 2 : 1.

In England pipe-clay occurs as a second layer below the sandy clay which is used in making tobacco pipes. This clay, owing to its possessing the property of contracting more than sandy pipe-clay, is not employed in the manufacture of earthenware; its component parts are,—

	Centesimally.
Silica,.....	53.66
Alumina,.....	32.00
Protoxide of iron,.....	1.35
Lime,.....	0.40
Magnesia,.....	trace
Water,.....	12.08
Loss,.....	0.51
	100.00

Pipe-clay also burns white in the fire, and, before the oxyhydrogen blowpipe it melts to a transparent, almost colorless glass.

Potter's clay.—Among the *fusible clays* may be classed *Potter's clay*, generally used for the production of the commoner kinds of clay-ware. It is distinguished from pipe-clay by the presence of a very sensible quantity of iron and some lime, is more easily disseminated through water, and has the same amount of plasticity as pipe-clay. The presence of lime causes it to effervesce slightly with acids. In color it is generally red, or brown-red, sometimes part-colored from the intermixture of various layers; is less homogeneous than pipe-clay; contains a considerable amount of organic remains, fragments of stone and iron pyrites; varies exceedingly according to the locality in which it is found, being sometimes fat, at others poor. The presence of the oxide of iron causes it always to assume a red or yellow hue after burning, and according to the quantities of this ingredient and of lime which it contains, it fuses more or less easily into a dark, vitreous mass or slag. The analysis of potter's clay, from different localities, gives the following results:—

By	Potter's clay from	Silica.	Alumina.	Iron.	Lime.
Aubert,	Provins—D. Seine et Marne—	57	37	4	1.7
Berthier,	Livernon—D. Lot—	61	30	7.6	2.4
Laureat,	Helsingborg,	60	24	7.5	0.5

The relation of the silica to the alumina in these specimens is, therefore, as 5 : 3, 2 : 1, and 5 : 2.

The common potter's clays in England are found in layers or strata lying over each other, each stratum possessing some distinctive property which fits it for a peculiar purpose. That which is called the sandy stiff, or ball-clay, is the upper layer, and from the considerable quantity of silica it contains is used for making salt-glazed ware. On analysis this clay, dried at 212°, will be found to yield:—

Silica,.....	66.68
Alumina,.....	26.08
Protoxide of iron,.....	1.26
Lime,.....	.84
Magnesia,.....	trace
Water,.....	5.14
	100.00
Its specific gravity,.....	2.558

Blue Clay, also one of the fusible clays, is considered the best layer of clay in the whole series. In color it is greyish, but burns perfectly white, approaching China-clay in character. When exsiccated at a temperature of 212°, its analysis, according to Mr. HIGGINBOTHAM, gives the following composition:—

Silica,.....	46.38
Alumina,.....	38.94
Protoxide of iron,.....	1.04
Lime,.....	1.20
Magnesia,.....	trace
Water,.....	13.44
	100.00

This clay is also called Dorsetshire and Poole clay. Poole being the port of shipment. It is obtained chiefly from the neighborhood of Wareham, and large quantities are shipped annually for Staffordshire and other parts of the United Kingdom.

These mines of clay are very large, extending upwards of seven miles from the port of shipment. The method of getting the clay varies according to the locality, and great trouble and expense are incurred in removing the superincumbent strata of soil, sand, and bituminous matter, which vary from sixty to eighty feet in thickness, the clay lying beneath a fine bed of sand. The heading of the clay is mixed with sand, and formerly was thrown aside as worthless; but of late years this has been extensively used for fire and fancy bricks, and for other ornamental and useful purposes. The bed of clay, once fairly laid open, is worked by cutting out cubical blocks weighing thirty to forty pounds each, with spades adapted to the work; and to facilitate the operation, currents of water are directed into small dams, into which the workmen constantly dip their spades: inspectors are engaged to examine the quality of the clay as it is taken from the beds, and to reject such as is not considered sufficiently good for shipment. The beds vary from three to six feet in thickness, and the latter is considered a profitable depth. The land from which the clay is procured is taken at a nominally low rental, but in consequence of the expense of removal of surface soil, the rental virtually is large. Returns of the quantities of clay raised are made from time to time, according to the terms of the lease. Railways are now in immediate connection with the mines direct to the port of shipment, and the clay is conveyed thence to Runcorn, where the cargoes are discharged, and forwarded by flats or small boats to the various manufactories throughout the district of the Staffordshire potteries.

The export of Poole clay, according to the Poole Custom House returns, reached in 1850, 54,877 tons; in 1851, 69,286 tons; and in 1859, about 102,000 tons. Many other clays of less value are obtained from the Poole bed.

The *Red or Brown Clay*, found in great quantities in

the vicinity of Glasgow, is a surface clay, the deep brown color of which results from the presence of a large quantity of sesquioxide of iron. It is in great demand for common black ware, flower-pots, and red bricks, articles which do not require to be exposed to any very high temperature which would fuse them. This clay, by analysis, yields—

Silica,.....	49.44
Alumina,.....	34.26
Protoxide of iron,.....	7.74
Lime,.....	1.48
Water,.....	1.94
Magnesia,.....	5.14
	100.00

An artificial yellow clay is obtained by a mixture together of sandy clay and red clay.

Fire-clay.—Another variety of clay, termed *Marl* or *Fire-clay*, is very abundant, occurring both on the surface and at various depths underground. From the porosity of its substance, it is well adapted to resist high temperatures, and its principal use in the potteries is for making seggars, or vessels for protecting the ware from the flames during firing. Fire-bricks, crucibles, and melting-pots for glass-works are made from this clay. Analysed, it gives the following composition:—

Silica,.....	66.16
Alumina,.....	22.54
Protoxide of iron,.....	5.31
Lime,.....	1.42
Magnesia,.....	trace
Water,.....	3.14
Loss,.....	1.43
	100.00

Fuller's-earth, a porous silicate of alumina, is a

Locality.	Silica.	Alumina.	Oxide of iron.	Carbonate of lime.	Carbonate of magnesia.	Alkali.	Analysts.
Abydos,.....	52.00	16.17	6.15	13.97	trace	trace	Salvetat.
Bonnefonds,.....	40.00	13.21	2.04	34.12	0.15	—	„
Belleville,.....	46.03	17.28	5.70	27.64	—	—	Buisson.
Chambray.....	49.50	29.00	3.00	18.00	0.50	trace	Laurent.
Savonc,.....	37.00	11.00	6.50	55.00	—	—	Buisson.
Viroflay,.....	39.00	18.00	1.00	40.00	trace	—	Lecog.
Villom,.....	30.00	20.00	2.00	46.00	—	—	„

A small portion of the lime in the marl is generally in combination with silica.

Loam is the commonest and least pure variety of clay belonging to the more recent alluvial formations; it is less uniform than any of the foregoing varieties—sand, gravel, stones, wood, roots, and all kinds of vegetal remains being mixed up with it in large proportions. The presence of hydrated oxide of iron gives it a yellow, spotted, and veiny color. Lime is also present, but in less quantity than in the marls. It is soft and easily reduced to powder, absorbs water with avidity, and forms with it a soft paste, which is much less plastic and fat than that obtained from pipe or potter's clay. As it occurs almost everywhere, it is the universal material for making bricks.

Ferruginous Clays, amongst which may be classed redde, bole, and ochre. The former two derive their red color from the presence of oxide of iron, the latter its yellow tinge from the hydrate of the same oxide. These varieties are used as pigments, but not for the same purposes as the other clays. From the large

fusible clay, distinguished from potter's-clay by its slight degree of plasticity. It is easily formed into a soft paste with water, and has a strong adhesion to oily matters, upon which depends the cleansing action of this clay upon woollen stuffs. The best clay for fulling cloth should be neither tenacious nor sandy; as in the first case it would not be easily diffused through water, and in the second it would abrade the cloth too much. The principal localities where it is found are in Bedfordshire, Berkshire, Hampshire, and near Nutfield, Ryegate, in Surrey.

CALCAREOUS CLAYS.—*The Marls*, a term which applies to all those deposits containing clay and carbonate of lime, the latter in considerable quantity. These mixtures being mechanical, and comprising all the intermediate formations between the limestone and the clays, are, from the variable quantities of the ingredient, multifarious in character. Those in which lime preponderates are named *Calcareous Marls*; those in which alumina is most abundant, *Aluminous Marls*. In general the marls afford the most fruitful soil for the purposes of agriculture. Aluminous marls are used in the manufacture of several kinds of pottery. They effervesce with acids. They are chiefly found in extensive stratified layers, consisting of a massive, but soft and pulverable substance, presenting an uneven, conchoidal fracture, easily permeable by water, and possessing but little plasticity; in color of a grey passing into brown. Aluminous marl is rarely of a uniform texture throughout, enclosing hard calcareous or silicious nodules; falls easily to pieces by exposure to the air, and is reckoned amongst the most widely diffused varieties of clay. The proportion of its constituents will be seen from the following analyses:—

amount of iron they contain they are sometimes classed with the ores of that metal.

Flint, quartz, silica, or *silicic acid*— Si O_2 —is found as an amorphous, black or brown colored mass, and occurs with chalk in roundish or irregularly shaped nodules, weighing from a few ounces to several pounds; it contains moisture, an organic substance, and occasionally iron. Whatever its original hue may be, it always burns white, and acts the part of a bleaching material, neutralizing imperceptibly the yellow or greyish color of the clay. In preparation for use, the flints are calcined in upright furnaces, constructed similarly to ordinary lime-kilns. The flint is thus rendered white and disintegrated, splits in all directions, and is sufficiently brittle and soft to admit of being crushed in the stamping mill, and ground under water in the block mill. A description of these processes will be given further on, under *Earthenware*.

CLASSIFICATION.—The production of earthenware from the different kinds of clays is effected by producing the proper form with the aid of the plasticity of

the clay, and afterwards modifying the formed vessels by heat in such a manner that they become no longer soft or flexible, but of a rigid stony consistence, permanently retaining their form, and able to resist the mechanical violence necessarily inflicted upon them by daily use. The quality of such vessels must necessarily vary according to the nature of the clay, the ingredients incorporated with it, the processes of purification, and the degree of heat of the furnace. Such differences are partly recognized by the color, texture, fracture, hardness, solidity, transparency, and chemical constitution of the ware, and partly by the sound produced by tapping. Many clay wares, *bricks and tiles*, have the appearance of being composed of various clays imperfectly mixed together, and containing foreign substances, as stones, *et cetera*. Other kinds again appear of a more homogeneous consistency, but resemble the former in the porous nature of the mass, which is soft, easily scratched, of an earthy fracture, little sonorous, and perfectly opaque. All ordinary pottery and earthenware, both ancient and modern, belong to this class.

There are other wares, again, such as *stoneware*, in which the mass combines a dense structure with considerable hardness, has lost its porosity and the properties connected with it, by the action of the intense heat of the kiln; produces a clear, sharp, ringing sound when struck; is somewhat translucent, with a fracture indicating an incipient fusion.

Porcelain exhibits the same properties—a fusible substance or *flux* being mixed with the clay.

Burnt clay-wares of a porous nature, and even non-porous vessels, to correct the roughness of surface, are generally covered with a vitreous coating or *glaze*, which, when it contains lead, is fusible and soft; when containing no lead, is refractory and hard. This glaze, according to the nature and requirements of the vessel, being laid on in thinner or thicker coats.

It is upon these and similar considerations that the classification of clay-wares is based.

CLASS 1.—Mass uniformly fluxed, dense, cannot be scratched with the knife, finely granular, *translucent*, very sonorous, white, and uniform.

PORCELAIN.—*Tender Porcelain*.—Mass easily fusible.

English.—Flux, bone-ashes—glaze containing lead and borax.

French.—A vitreous mass, containing no clay, with a lead glaze of harder consistence.

Real Porcelain.—Mass difficult of fusion; flux, a refractory glass, composed of silicate of alumina and potassa; glaze of a similar nature, often containing lime.

CLASS 2.—Mass dense, cannot be scratched with the knife, sonorous, finely granular, uniform, exhibiting incipient fusion, scarcely translucent—or only on the edges—white or colored.

STONEWARE.—*Common Stoneware*.—Mass of a reddish grey or bluish color, generally without glaze, a salt glaze only.

Ironstone Ware.—Mass generally white when it contains a flux, and has a lead glaze; artificially colored, also, without glaze.

CLASS 3.—Mass earthy, porous, pretty hard, opaque, texture open, little sonorous.

EARTHENWARE.—*Fine Earthenware*.—Mass white,

hard and sonorous; glaze of crystal, soft, containing lead.

Delft Ware.—Mass finely granular, uniform, more or less tinged yellow; glaze, a soft white or colored enamel.

CLASS 4.—Mass earthy, very porous, opaque, soft, homogeneous texture, always colored.

Ordinary Pottery.—Partly glazed and partly unglazed; the glaze may contain lead or not, but is always easy of fusion, and transparent.

Lustre Ware.—Mass earthy, porous, opaque, very soft; texture not uniform; glaze metallic and not transparent.

CLASS 5.—Mass more or less not uniform, always colored, very soft, porous, and open. little sonorous, and opaque.

Bricks, Tiles, Ornaments.—Sometimes glazed: mass fusible at a high temperature.

Fireproof Stones, Crucibles.—Mass difficult of fusion, or infusible; not glazed.

PORCELAIN.—*Tender Porcelain*.—This appellation has reference not so much to the hardness of the clay, as it has to the feeble resistance offered by this class of wares to the high temperature of the kiln, and the softness of the glaze, compared with true porcelain. It may be classed under two heads:—Natural, or the tender porcelain of England, in which kaolin or China-clay is the basis; and artificial, or the tender porcelain of France, in which the mass is a mixture of different substances, consisting mainly of silica, with alkaline and earthy salts.

English Tender Porcelain.—So named because the manufacture is exclusively confined to this country, local reasons being unfavorable to the production of true porcelain. The chief of these is the want of a cheap material for the construction of the seggars able to stand the firing, the present loss of seggars in Staffordshire being estimated at from eight to ten per cent. at each firing.

The crude materials which enter into the composition of ironstone China are *plastic clay*, *kaolin* or *China-clay*, and *granite* or *Cornish-stone*, with *chalk flints*, and occasionally *steatite* or *soap stone*, which contains magnesia, 44; silica, 44; alumina, 2; iron, 7.3; oxide of manganese, 1.5; oxide of chromium, 1.2, with traces of lime and chlorine—the action of which is said to diminish the contraction of the wares in the furnace. The bones, which are obtained either from native cattle or by importation, may previously have been employed for the extraction of gelatin or glue, or, for the production of ammoniacal salts by dry distillation, or may be used in the form of animal charcoal; but before they are applicable to the present purpose, they must be thoroughly calcined by being heated to redness with free access of air, so as to destroy all their organic constituents and leave only the mineral ash, phosphate of lime, carbonate of lime, and a little magnesia, in the form of a perfectly white substance. The phosphoric acid diffuses itself at a high temperature through all the materials, uniting them into a translucent enamel, which, being less apt to shrink and lose its form than the hard China body, may be baked in larger kilns, and with less risk of loss

to the manufacturer. All these ingredients are ground, suspended in water, and evaporated into the form of paste in the manner to be afterwards described under *True Porcelain* and *Earthenware*. A frit is then prepared, of which the mass is made up with other substances, as follows :—

FRIT.	
Bone,	100
Sand,	90
Pearlash,	7

MASS.	
Burnt bone,	600
Kaolin,	300
Cornish-stone,	360
Frit,	40

or the mass is not fritted in part, but, as in the case of table-ware, mixed all at once, in the following proportions :—

Bone,	450
Cornish-stone,	200
China-clay,	160
Plastic blue clay,	45

Other mixtures for English China-ware may be given as follows :—

I.	
Bone,	46
China-clay,	23
Cornish-stone,	31

II.	
Bone,	36
Cornish-stone,	21
Cornish-clay,	21
Flint,	12

III.	
China-clay,	600
Felspar,	335
Bone,	840

IV.	
Bone,	320
China-clay,	225
Cornish-stone,	230

The bone and flint are sometimes fritted to produce the highest degree of vitrescence, and then mixed up with other ingredients. A little Dorset clay is frequently added for large pieces, as dishes, *et cetera*, to give more ductility in working and greater stability in the fire. In all cases the ware, from the large proportion of clay in the mass and its extreme plasticity, requires to be fired twice. The first firing lasts longest, being of from forty-eight to fifty hours' duration; and the temperature is gradually raised during the whole time, the heat of the kiln, ranging, according to the composition of the ware, from 100° to 110° Wedgwood's pyrometer. It is somewhat singular that this instrument is never used in the potteries, the proper temperature being regulated by small trial pieces of the same material as the goods to be fired. The average quantity of coal consumed at a firing is from ten to twelve tons. When the trial pieces show that the heat is sufficiently raised, the firing is discontinued, the fire and ashpit doors closed, and the whole left to cool during twenty-four or thirty hours. The glaze is then applied to the ware, and the articles undergo a second firing, but neither at so high a temperature nor of so long duration; and in this consists the essential difference between English and foreign

manufacture; abroad the greatest heat being applied to the glazed vessels, and not to the biscuit ware.

GLAZES.—The porosity of ordinary porcelain seems early to have suggested the use of a glaze, or thin glass covering, for the purpose of rendering it impervious to fluids. The composition of such glazes requires to be such, that when they are exposed to the necessary heat, they shall unite with the body or paste; and that in cooling they may not split, crack, or craze, from occupying less volume in their fired state, and their consequent inability to completely cover or envelope the body of the ware underneath. Those most commonly used are flint, quartz, sand, felspar, gypsum or sulphate of lime, carbonate of lime, borax, boracic acid, chloride of sodium, potassa, soda, and oxide of lead. Some glazes are first formed into *frits*, imperfectly vitrified bodies so termed, and afterwards pounded for use.

Colored glazes are made with the addition of nearly pure oxides of manganese, copper, iron, chromium, cobalt, *et cetera*; *opaque glazes* or enamels, by the addition of oxide of tin, or phosphate of lime; for which see *Porcelain True* and *Earthenware*. Some of the ordinary lead glazes for soft porcelain are given below :—

Cornish China-stone,	100
Calcined flint,	60
Carbonate of lime,	25
Cornish kaolin,	10
Soda,	10
Borax,	60
Carbonate of lead,	30

These ingredients are all fritted together with the addition of twenty per cent. carbonate of lead and ten per cent. flint :—

Cornish China-stone,	34
Chalk,	17
Ground flint,	15
Borax,	34
100	

which substances, when fritted and ground together, are mixed with ten per cent. of Cornish-stone and twenty-one per cent. of carbonate of lead. The lead is sometimes omitted from the mixture, and the requisite fluidity of the glaze maintained by an additional quantity of borax :—

Cornish China-stone,	25
Soda,	6
Borax,	3
Nitre,	1

fritted together in gloss oven, and the mixture used in the following proportion :—

Frit,	26
China-stone,	26
White lead,	31
Flint,	7
Carbonate of lime,	7
Oxide of tin,	3

the whiteness being increased by the addition of a little oxide of cobalt. Another glaze for tender porcelain is given below :—

Felspar,	38
Lyonsand,	24
Carbonate of lime,	11
Borax,	27

fritted together and mixed as follows :—

Frit,	60
Cornish-stone,	20
White lead,	20

Other glazes are:—

Cornish-stone,	52
Flint,	38
China-clay,	30
Carbonate of lime,	45
Borax,	90

fritted together and mixed as follows:—

Frit,	320
Cornish-stone,	50
Flint,	50
White lead,	60

Another as follows:—

Cornish-stone,	60
Felspar,	60
Flint,	75
Carbonate of lime,	40
Borax,	100

fritted together and mixed as follows:—

Frit,	250
Cornish-stone,	65
White lead,	65

The temperature of the glaze kiln ranges about 60°

Wedgwood, but is varied according to the circumstances of the manufacture. The time required for firing the glaze kiln averages about seventeen hours, the consumption of coal being nearly six tons. The lead and borax glaze of this kind of porcelain, although soft, is sufficiently pure and brilliant for the purpose of ordinary painting, decoration, and gilding—see *Porcelain*.

The chemical composition of three kinds of English tender porcelain, together with the analyses of clays and porcelain when freed from water, is shown in the following table:—

	I.	II.	III.
Silica,	29.88	40.60	39.685
Alumina,	21.48	24.15	24.650
Lime,	10.06	14.22	14.175
Protoxide of iron, }	26.44	15.32	15.386
Phosphate of lime, }	—	—	—
Magnesia,	—	4.3	3.11
Alkali and loss,	2.14	5.28	5.792
	100.00	100.00	100.000

TABLE OF THE COMPOSITION OF CLAYS AND PORCELAIN WHEN FREE FROM WATER.

	Silica.	Alumina.	Protoxide of Iron.	Lime.	Magnesia.	Phosphate of lime and protoxide of iron.	Alkali and loss.	Specific gravity.
Cornish China-clay,	53.16	45.61	.31	.41	.51	—	—	—
“ “	53.12	46.00	.31	.57	.51	—	—	—
Sandy clay,	70.29	27.47	1.33	.90	trace	—	—	2.558
Pipe “	61.39	36.61	1.54	.46	—	—	—	—
Blue “	53.52	43.89	1.20	1.39	—	—	—	—
Red “	52.11	36.19	8.17	1.56	2.04	—	—	—
Fire “	69.33	23.62	5.56	1.49	trace	—	—	—
Yellow “	65.06	30.68	3.70	.56	—	—	—	—
English China-ware—No. 1, ..	39.88	21.48	—	10.06	—	26.44	2.14	—
“ “ 2, ..	40.60	24.15	—	14.22	.43	15.32	5.28	—
“ “ 3, ..	39.68	24.65	—	14.18	.31	15.39	5.79	—
Berlin ware,	72.96	24.78	—	1.04	trace	—	1.22	2.419
Superior China-ware,	71.04	22.46	—	3.82	—	—	2.68	2.314
Inferior “	68.96	29.24	—	1.60	—	—	—	2.314
Common English whiteware, ..	68.55	29.13	—	1.24	—	—	—	2.369

The *Artificial Tender Porcelain of France* presents the following characteristics:—*Body* fine, dense, texture almost vitreous, hard, translucent, fusible at a high temperature; *glaze* vitreous, transparent, containing lead, and tolerably hard. The composition of the artificial porcelain of France differs materially from the tender porcelain of England, as will be seen by the mixtures—mainly silica, with alkaline and earthy salts—used at Sèvres, where the manufacture of this class of ware was carried on most extensively between the years 1750–1804. During this period it obtained great celebrity, and from the circumstance of the manufacture being now no longer continued, having given place to the improved method of BÖTTICHER, the following composition is now interesting as a matter of curiosity:—

Melted saltpetre,	110
Sea-salt grey,	36
Alum, generally burnt,	18
Alicant soda,	18
Gypsum from Montmartre,	18
Sand from Fontainebleau, ..	300
	500

From the almost entire absence of clay in this fritted composition, the mixture must altogether be excluded from clay wares, being in fact neither more nor less than a glass mixture, which, if submitted to complete fusion, would yield an alkaline glass. The heat, however, to which this mixture is exposed only admits of a partial

vitrefaction, the fritting being effected in the calcining furnace. It is then crushed and lixiviated in order to remove the soluble salts not decomposed by the silica, and ground with millstones under water to a fine powder in order to form a paste. Certain proportions of chalk and calcareous marl, ground and brought into the finest state of division by suspension in water, are then added to the powdered frit, and compose the mass for the formation of the ware, the nature of this mass becoming more or less vitreous according to the proportions of chalk and marl employed. At Sèvres, for every seventy-five parts of frit, seventeen parts of chalk, and eight parts of calcareous marl were used—the whiteness and hard or soft texture of the body being modified by the preponderating quantity of the chalk.

The glaze or enamel, a kind of crystal, was composed as follows:—

Litharge,	38
Sand from Fontainebleau, burnt,	27
Calcined flint,	11
Subcarbonate of potassa,	15
Subcarbonate of soda,	9
	100

The higher degree of transparency, together with the softer nature of the lead glaze, is one of the distinguishing features of soft from real porcelain. The manner in which the paste was formed into vessels is similar to that in the other branches of the manufacture

—see *Earthenware* and *Porcelain*. But the almost entire absence of clay, depriving the mass of plasticity, rendered the operation one of great difficulty and expense, the cohesion between the particles being extremely slight. This defect was partly overcome by the admixture of one-eighth part of soap and glue, or gum tragacanth, which imparted so much tenacity to the composition as enabled the mass either to be formed in gypsum moulds, or turned upon the potter's lathe. The operation of firing was one likewise of considerable risk, from the vitreous nature of the mixture; the prominent portions of the ware being often either fused or so softened by the heat as to lose their shape. Such defects could only be remedied by suitable supports, at a great expenditure both of time and trouble. The first firing, which was of longer duration than in the case of real porcelain, extended over a period of from sixty-five to a hundred hours; the glaze was afterwards applied to the vessels, and fired for a further period of thirty hours. The colors employed in the decoration of this species of porcelain required careful and particular treatment and preparation. In firing, the dishes and wares, instead of being placed in the kiln in a horizontal position, were suspended on pegs in a vertical direction to avoid fracture, which otherwise would have occurred. The point of suspension—a small hole—will be readily discernible on the under side of all Sèvres porcelain, and indicates a remarkable feature in the process of the manufacture.

Foreign Porcelain or *China* is the finest and most valuable description of ware, distinguished from other wares by the composition of the paste from which it is formed, giving a body of a fine, hard, translucent texture. Great care is exercised in the selection of the materials to give a colorless mass after firing. Two essentially

different constituents enter into its formation, one an infusible, plastic, white clay, called *kaolin*, or China-clay; the other a fusible, non-plastic material, the so-called *flux*, composed of felspar, with the addition of quartz, chalk, and gypsum, which, softening and becoming vitrified in the heat of the porcelain kiln, forms a kind of cement, binding the clay firmly together, and producing a dense, impenetrable, translucent mass, of a uniform texture throughout, and impervious to liquids. The transparency of porcelain arises, therefore, from the clay body becoming saturated with a mass of glassy flux. Under the microscope the two ingredients can be clearly distinguished from each other, the milky mass appearing as a transparent ground, mixed with an opaque substance, composed of minute globules, arranged in a lineal direction, one on the other, as articulated threads or little rods, which are interwoven and cross each other in all directions; the want of absolute transparency in the mass being due to the reflection and refraction of light from the surfaces of these crystals.

The *Glaze*, equally characteristic with the mass, is composed of *felspar*, sometimes mixed with a little gypsum, but with an entire absence of lead or tin; it is, consequently, of the same nature as the flux, and can be brought into the most intimate union with the flux and the mass, securing another essential characteristic of porcelain—the non-separation or peeling of the glaze from the vessel by any outward shock or sudden changes in temperature. The expansive and contractile powers of the glaze being assimilated to that of the body, it is not affected by high temperature, and its surface is less liable to the crazing so often discernible upon other kinds of clay wares. The absence of lead causes the glaze to be very hard, and to resist scratching. The mass for porcelain vessels is composed as follows:—

FINE OR HARD PORCELAIN—COMPOSITION OF THE MASS.

IN BERLIN.		IN VIENNA.	
For Domestic Uses, Plates, Dishes, &c. <i>cetera</i> .		For Ornamental Purposes.	
Kaolin from Morl,	76	Kaolin from Morl,	25
Felspar,	24	Kaolin from Beidersee,	50
		Felspar,	15
		Pure sand,	10
IN SEVRES, NEAR PARIS.		IN ST. PETERSBURG.	
For Vessels		For Tableware.	
Kaolin from St. Yriex,	48	Kaolin from Risansky,	50
Sand, separated from above, containing felspar,	48	Felspar, Finland,	25
Chalk,	4	Quartz,	25
IN MEISSEN, SAXONY—COMMONLY CALLED DRESDEN PORCELAIN.		IN COPENHAGEN.	
For Domestic Purposes		For Low Temperatures.	
Kaolin from Aue,	18	Kaolin from Passau,	62.5
" " Sosa,	18	Quartz,	19
" " Seilitz, 36	36	Sand separated by water from kaolin,	6
Felspar,	26	Gypsum,	5
Broken biscuit porcelain,	2	Broken porcelain,	7.5
		For High Temperatures.	
			65
			21
			4
			5
			5

The following analyses of foreign porcelain are given, as having been recently made:—

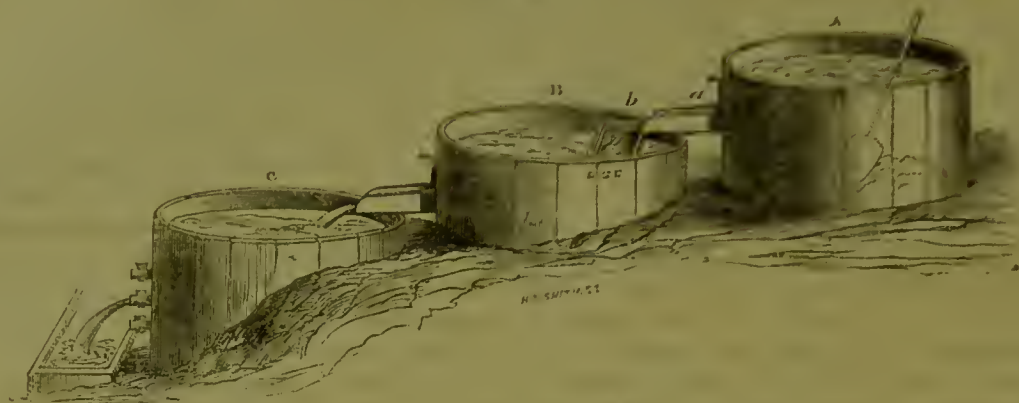
	Berlin.	Chinese.	
		Superior.	Inferior.
Silica,	72.96	71.04	68.96
Alumina and protoxide of iron,	24.78	22.46	29.24
Lime,	1.04	3.32	1.60
Alkali,	1.22	2.68	—
	100.00	100.00	99.80
Specific gravity,	2.419	2.314	23.14

Preparation of the Material.—Crude kaolin is not sufficiently pure for the purpose of manufacture, being a mixture of real kaolin with undecomposed felspar and particles of quartz, both of which must be separated or finely ground and mixed, to form a uniform substance throughout. This process of washing and suspending in water, which precedes the grinding, is generally undertaken at the porcelain works, though in some cases it is partially effected at the pits.

The decanting or elutriating apparatus consists of three tubs or basins, A, B, C, placed one above the

other—Fig. 466—the kaolin being put into the first tub. A, two men thoroughly mix the mass up with water

Fig. 466.



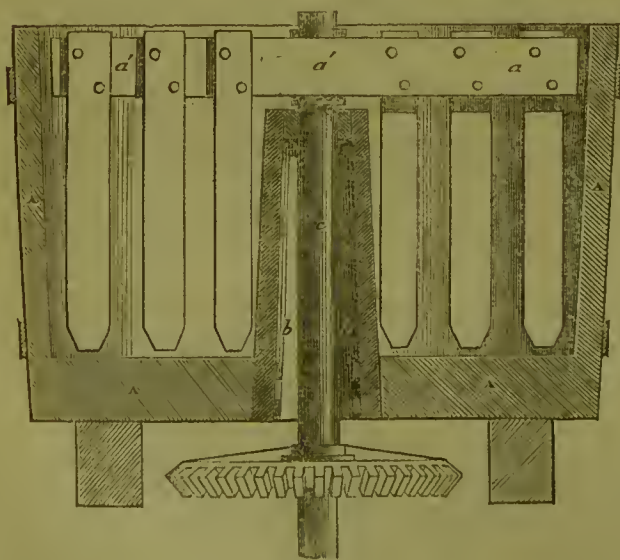
by stirring it with wooden spades or blungers. When every part has been thoroughly elutriated, the mixture is allowed to run off by the removal of a plug along the channel, a, situated a few inches above the bottom, into the vat, B, the stones and coarser particles remaining behind, while those carried forward are arrested by the sieve, b, leaving only the decanted liquid containing fine sandy particles mixed with real kaolin. After a further stirring, and remaining for a short time at rest, the sand subsides completely to the bottom, the liquid carrying with it only the argillaceous kaolin into the lowest vessel, where it is allowed to deposit completely before the water is drawn off from the finely-divided clay. Sometimes, as at Sèvres, there are six of these filters, at each of which two men are employed, the small particles of wood, straw, and other light bodies, which of themselves would not fall to the bottom, but float, being separated from the mixture or *slip*—a term in pottery technically applied to any preparation of clay in a state of suspension in water—in its passage from

particular kind of sand and crude kaolin. Sometimes machinery is employed instead of manual labor, for the stirring or kneading up of the mass with water. A vat, A—Fig. 467—is furnished with revolving arms, a' a' a', armed with wooden oars or blungers, which, in their revolution through the mass, effect the requisite kneading and mixing. Before the liquid is withdrawn into the subsiding vats. The shaft, c, carrying the arms, is inclosed in a second hollow shaft, b, to protect the mixture from dust and oil.

Chalk from Bougival is a constant addition to the porcelain paste. The chalk contains about ninety-five per cent. carbonate of lime. Its analysis is as follows—

Carbonate of lime,	95.50
Carbonate of magnesia,	0.80
Silica,	0.50
Water,	1.20
Iron, manganese, and alumina,	1.70
	100.00

Fig. 467.



one to another, by passing through hair sieves. This process of decantation supplies a sufficient amount of felspar and quartz in the state of sand, the strong and argillaceous varieties giving each their

Limestones of equal purity may be substituted for the chalk. At Nymphenburg, as in Meissen, fragments of old porcelain are also added, the mixture of which, when allowed to exceed a certain proportion, injures the plasticity of the paste. For the production of the best class of porcelain much depends upon the careful selection of the kaolin and material, the cost of manufacture being the same. With inferior clay the porcelain loses its whiteness, its sonorous ring, and much of its value. Kaolin, to be regarded as of the first quality and suitable for the finest manufacture, should possess a body of a beautiful white color resembling pure milk, entirely free from all foreign substances, however minute, capable of producing stain or blemish in the subsequent processes of manufacture; also the porcelain body formed from it should be easily worked without fear of cracking, neither too fusible nor too argillaceous; for although it may be possible to correct these faults by appropriate mixture, the mass never turns out so satisfactory. Great care must likewise be bestowed upon the uniform incorporation of the ingredients, so that everything of a coarse and massive nature, as felspar, chalk, gypsum, broken porcelain, *et cetera*, be reduced to the finest state of division, and the rejection of all particles of iron, mica, *et cetera*, which sometimes occur, and the

presence of which might impair the whiteness of the china. Mills are, therefore, employed for this purpose. A vertical section of one is given in Fig. 468. Two millstones, *a* and *b*, are inclosed in a

a b, the bearings of which are secured in solid masonry or framework. *c* is a shaft passing through a boss head, *e*, in the axle, *a b*, and carrying with it a strong framework, *E E*, bedded with stone, upon which the

Fig. 468.

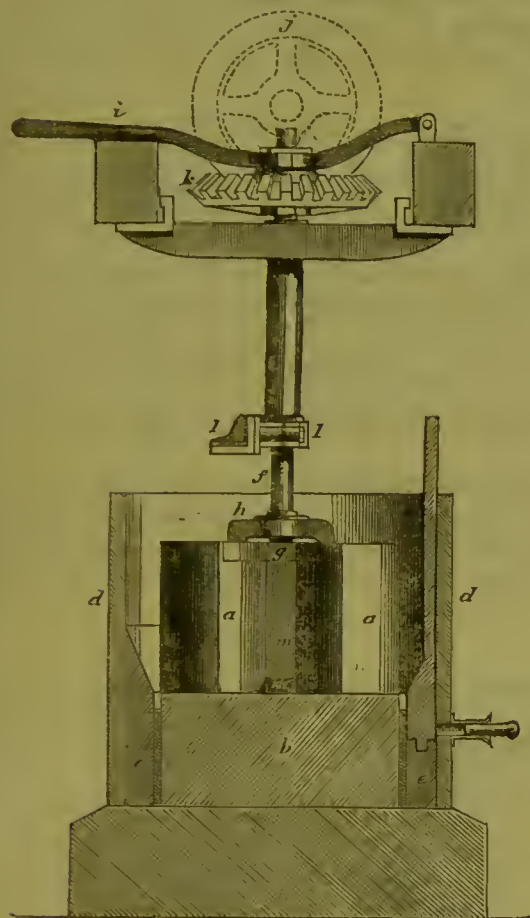
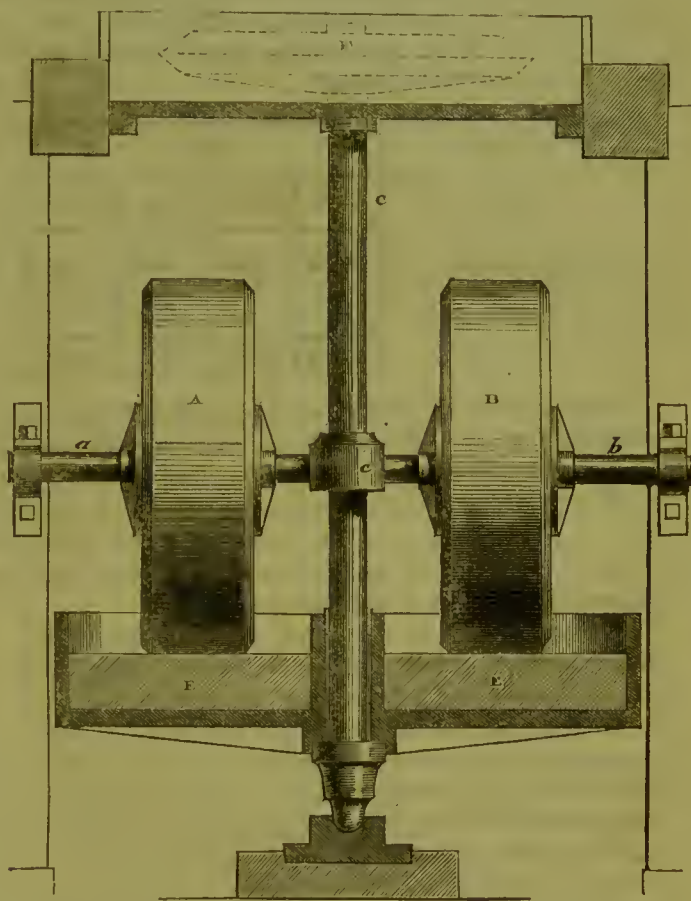


Fig. 469.



cylindrical case or framework, *d*, bound together by hoops, the lower one, *b*, being fixed into position by the wedging, *e*, while the upper one, *a*, revolves by motion communicated to it through the shaft, *f*. This shaft is keyed to the stone by means of a metal casting, *g*, let into its upper surface, which receives the coupling arm, *h*, attached to the lower extremity of the shaft, where it is depressed by the lever, *i*. *j* and *k* are two bevil wheels to which motion is given either by steam or water power, the axle of the horizontal wheel, *k*, being hollow and supported by bearings, *l l*. The shaft, *f*, in direct communication with the millstone, passes through this hollow casing, the rotatory motion of which is imparted to it by the spurs of the lever, *i*, when lowered, coupling with those of the arms of the revolving wheel, *k*. In order to guide the material better in a downward direction, the upper stone, *a*, is not perfectly round, but hewn flat on two sides, with two grooves, *m m*, cut opposite to each other. If the pieces of stone are of larger dimensions than these spaces, they will, of necessity, be excluded from the spot where the titration is effected. They are, therefore, previously taken to the crushing machine, and brought to a uniform size. Fig. 469 represents a mill for this purpose. *A* and *B* are two circular millstones, mounted with free motion upon a fixed axle,

mill-stones revolve and crush the material thrown in. The revolution of this mass is effected by the spur-wheel, *F*, driven by steam or other power. The materials in every case having been ground, and the clay separated from its coarser particles by elutriation in the manner described under *Kaolin*, are in a state of very fine powder, and mixed together in various proportions according to the manufacture. This is effected by mixing the several ingredients, felspar, kaolin, *et cetera*, by measure in a liquid state, the proportion of weight of solid matter contained in a cubic foot of each separate specimen of *slip* having been previously ascertained, and none of the material being allowed to settle down, but each forming a thickish uniform semiliquid mass.

This method of mixing, although more accurate than that of weighing, does not always give the exact proportion required, in consequence of the changeable nature of the kaolin, which contains sometimes more or less silica and alumina, and these, with the variation in the quantities of potash and lime, materially affect the qualities of the paste. The best proportions of the mass have been determined from a mean of several analyses of the best porcelain manufactured at Sèvres between the years 1770-1836; and are found, according to the results of experience, to be as follows:—

Silica,.....	58.0	Lime,.....	4.5
Alumina,.....	34.0	Potash,.....	3.0

It is, therefore, only necessary to make an analysis of each of the crude materials that are to be mixed together, to ascertain the quantity of silica, alumina, lime, and potash each contains, in order to obtain the data for calculating how much of each by weight, and consequently by measure in their semifluid state, will be required to obtain the proper mean quantity as nearly as possible in the mass.

It is worthy of remark, however, that artificial proportions are never so satisfactory in their results as the same when occurring in the natural condition of the kaolin.

Every importation of kaolin being chemically a different mixture, the proportions used of it will vary each time; but the mass must always contain the same quantity of elementary constituents, as the following mixtures of 1839 and 1843 will demonstrate:—

Mixture of 1839.		Contains				Mixture of 1843		Contains			
Composed of		Silica.	Alumina.	Lime.	Potash	Composed of		Silica.	Alumina.	Lime	Potash
73 Decanted kaolin,		38.69	30.66	0.73	1.75	48 Kaolin,.....		30	16.90	0.05	0.96
24 Felspathic sand,		19.27	3.40	—	1.27	48 Felspathic sand,....		28.30	17.04	0.53	2.01
3 Lime.....		—	—	3.77	—	4 Lime,.....		—	—	4.00	—
		57.96	34.06	4.5	3.02			58.03	33.94	4.58	2.97

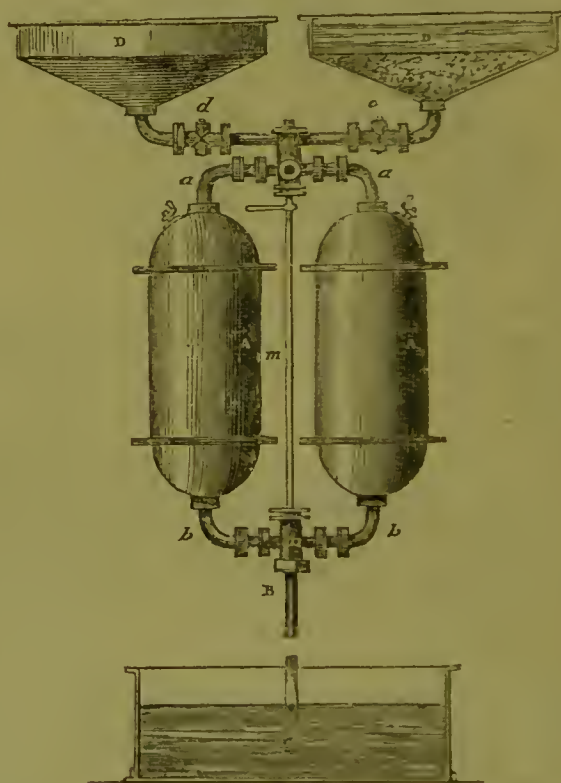
It is not to be understood that the practice at Sèvres is applicable to all other localities, or that every species of porcelain, possessing the same elementary composition, should exhibit the same properties; for even supposing the composition in one hundred parts to be identical, very much depends upon the nature of the proximate ingredients in the mixture.

The incorporation of the mass is effected in large cisterns or tanks under constant stirring, the paste being afterwards so far freed from water as to form a kneadable, dough-like mass. As this cannot be effected by subsidence, in consequence of the heavier felspar particles falling by gravity to the bottom and causing a disintegration of the mass, recourse is had sometimes to ebullition and evaporation, by which constant currents are kept up in the liquid, and any separation of parts is prevented. This process, however, is not well adapted to porcelain mixture, as it impairs its plasticity, and causes it to become, in technical language, *short*. Other methods are, therefore, substituted—one of which consists in drawing off the paste or slip into long shallow troughs, having their bottoms composed of gypsum, the porosity of which absorbs the moisture from the paste. In this process the gypsum beds require to be repeatedly dried by a gentle heat or by the action of air. Latterly, however, the application of gypsum, as a drying agent, has been superseded by direct pressure, either applied mechanically or by means of the atmosphere. In the former case the mixtures are inclosed in sacks of a strong and closely woven texture, the threads being carefully freed from filaments so as not to attach themselves to the paste, and which previous to use have been well soaked in hot linseed oil, giving them more durability and permeability to water. A number of these bags being placed between two boards, pressure is economically applied by means of a long lever loaded upon the long arm, and having the shorter arm placed against one of the boards, so that in this way the pressure may be maintained as long as desirable. A press of this description will prepare for use about thirteen hundred pounds of paste in three hours; and the process, though not more economical, has the

advantage of communicating greater plasticity to the mass.

Another more refined and successful plan, invented by M. L. TALABOT, consists in applying atmospheric pressure under vacuum to extract the water from the mass. Two vessels, or chambers, A A—Fig. 470—are

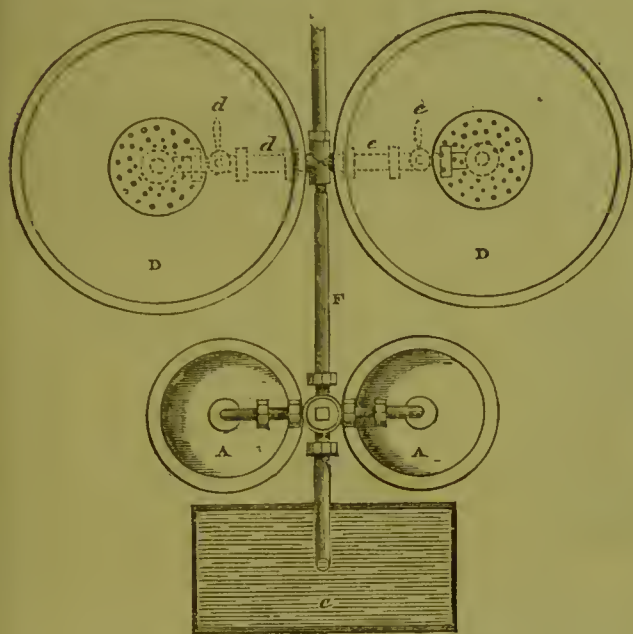
Fig. 470.



placed in connection with a pipe, B, of about thirty-six feet in length, by the tubes, a a, b b, furnished with stopcocks. The extremity of the pipe, B, is immersed in a reservoir of water, c. If one of the chambers, A, be filled with water by the pipe, F—Fig. 471—the stopcock being opened so as to communicate with the reservoir by the pipe, B, a vertical column of water will be formed of from forty to fifty feet in height, but the atmospheric pressure being only equivalent

to a column of about thirty-four feet, the vessel, A, will discharge its contents, by means of the pipe, into the reservoir, C, and form a vacuum above. The filtering vessels, D, D, placed above and communicating

Fig. 471.

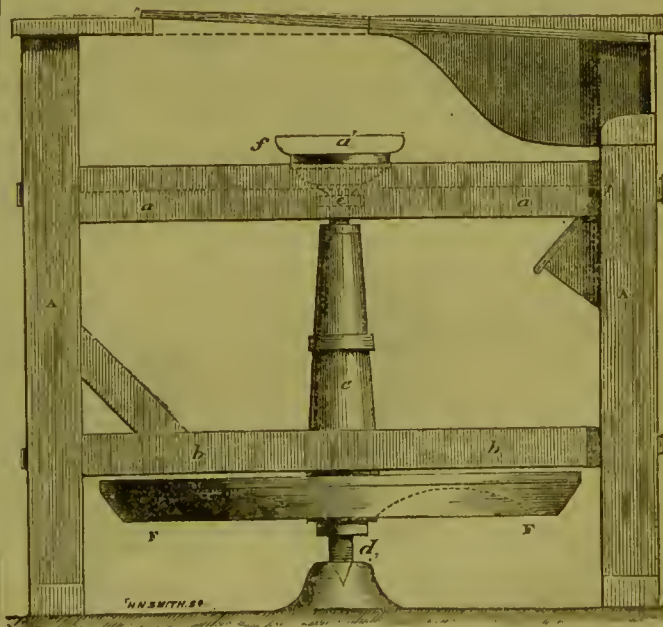


with the reservoirs, *A, A*, by pipes and stopcocks, *d* and *e*, are of a conical form; iron gratings are placed within over the orifices of the pipes, and a bed of pebbles is made to fill up the conical portion, over which a cloth of a thick spongy felt is placed—permeable to water, but not to the solid particles of the slip—and firmly secured to the edges of the filter; upon this another cloth of hemp receives the slip. Upon depressing the rod, *m*, which works through the two air valves, *nn*, a direct communication is opened above and below between the reservoir and one of the vacuum vessels, and the atmospheric pressure not being counterbalanced below, exerts its whole action upon the surface of the slip, forcing the water through the filtering cloth into the vacuum. In the course of forty or forty-five minutes a layer of slip of six inches deep, containing rather more than fifty per cent. of water, is reduced to a thickness of two and a quarter inches, and converted into a paste of remarkable plasticity, containing only one-fifth of water. In whatever manner this drying of the paste is effected, it is always obtained of equal consistency, the paste from the sacks or pressing apparatus being firmer on the outside than in the interior. This defect is obviated by a process called *slapping*, the clay, generally preserved in the form of lumps or balls, being forcibly thrown repeatedly against a hard stone or slab of gypsum, rendering it perfectly homogeneous throughout. Sometimes treading under foot, or laceration between metallic plates with a stamper, is substituted for the slapping process.

The felspar and lime in the paste, not being plastic ingredients, and always amounting to one-fourth or more of the whole, considerably interfere with its

plasticity, rendering it very much below that of pure clay. The forming and moulding process is consequently one of great expense and difficulty, so much so, that while a workman employed with assistants in preparing plates from the more plastic earthenware, can produce six hundred in ten working hours, not more than sixty or eighty plates of porcelain can be moulded in the same time. Every precaution and endeavor is, therefore, used to increase its plasticity—such as mixing it with fragments from the moulding operation, continued treading and kneading, and, what is found to be of greater utility, the storing it away in moist layers, in order to engender a peculiar species of decay. The superior value of clay that has been kept a considerable time is well known, and it is never desirable to work paste that has not been stored away in a moist state at least for a year. During this process of *aging*, a curious phenomenon occurs: a fetid smell of rotten eggs is evolved from the mass or lump, the interior portion becoming of a darker color passing from grey to black. This black color is produced by the highly carbonaceous product of the decomposition of organic matter, which, by a constant absorption of oxygen, reducing the gypsum and other sulphates that may be present to the state of sulphides, gives rise to the production of sulphide of hydrogen on the outer portions; and wherever the air has access to the blackened part, the black matter disappears, the oxygen being converted under these circumstances into carbonic acid. It is more difficult to assign a reason for the greater plasticity of the mass that has passed through this process, though it may be probable that the gas, in struggling to escape, more completely pul-

Fig. 472.



verizes the clay, and reduces the whole into a homogeneous mass. So fully aware are manufacturers of the efficacy of this fermentation, that attempts are sometimes made to induce it by the addition of honey, sirup, *et cetera*, to the mixture.

Forming or Moulding of Porcelain.—Porcelain

bodies being more susceptible of inequality of pressure in the process of turning and moulding than earthen-ware, require a corresponding greater amount of care. The goods are formed either upon the *pott r's lathe* or *throwing wheel*, in *moulds* or by *casting*. The art of *throwing* by the potter's wheel is the most ancient, as well as, from the skill it requires on the part of the workman, the most interesting. The form in which it is now employed in the porcelain manufacture is shown—Fig. 472.—The disc, *a*, consisting of the head, the axle, and the wheel, is placed in the middle of a table, *A A*, supported by massive framework, and bound together by cross-bars, *a a, b b*. The axle, *c*, is made of iron, one end, *d*, rotating on a piece of quartz cemented to

the floor by plaster of Paris; while the other, passing through the brass ring, *e*, screwed to the table, carries the massive block of gypsum, *f*, upon which the operation of forming or throwing is performed. To the lower portion of the axle a wide heavy horizontal wheel, *r r*, is attached, which, from its great weight, mostly accumulated in the circumference, works as a balance wheel, rendering the motion in the upper part, *f*, uniform and continuous—a matter of considerable importance.

The *thrower* or workman engaged in the formation of the plastic clay seats himself upon the stool, *a*—Fig. 473—supporting himself with his feet against the band *b*, so as to obtain a sufficiently stable position to

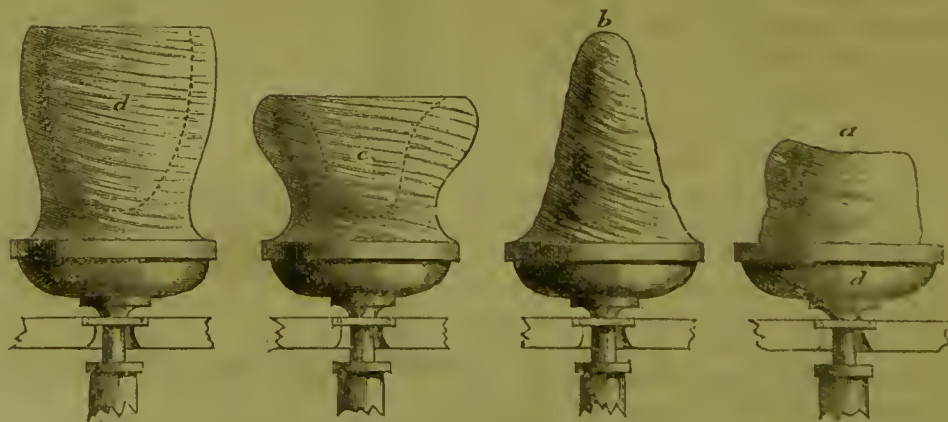
Fig. 473



enable him to rotate the wheel, *c*, with one foot. The mass of dough, as received from the *slapper*, is cut up into portions by means of a brass wire, each portion being weighed by an assistant called the *baller*, accord-

ing to the size and value of the article. The thrower receives one of these masses, and dashes it down upon the centre of the revolving block of gypsum, *d*. The thrower now presses both hands against the mass,

Fig. 474.



which being kept in constant rotation gradually acquires a round form, *a*—Fig. 474—his hands being maintained in a smooth state by dipping them into a vessel containing a quantity of water and paste held in suspension. If it were not for this precaution the

paste would adhere to the skin, and the smoothness of its surface be destroyed. The next operation consists in rendering the piece as homogeneous as possible, by raising it into the tall conical mass *b*—Fig. 474—for the purpose of squeezing out the air. The workman

then forces both his thumbs downwards into the centre of the mass, producing a cavity, which is enlarged as he removes his thumbs one from the other, *c*—Fig. 474—producing a bell shape. The sides of the half-finished vessel are then closely pressed in a slightly upward direction between hands and thumbs, and being lessened in thickness increase correspondingly in height, *d*—Fig. 474—according to the nature of the required vessel. It is in this manner that all vessels of a circular form in horizontal section, *c*—Fig. 473—are produced.

When the mouth of the piece is too narrow to admit the insertion of the hand, as is often the case with a jug, it is either made in two halves, afterwards cemented together, or shaped out by means of a wet sponge attached to the end of a crooked stick. In order to insure uniformity in the sizes of the piece, a gauge is used, consisting of a small rule, *a*—Fig. 475—sliding up and down a rod, *b*, and fixed to any required height by the marker, *c*, the whole being attached to the stand, *d*.

In this process of forming by the hand upon the lathe, the inequalities of the skin produce serrated spiral lines upon the surface of the ware, destroying its neatness and cleanliness. This circumstance, in conjunction with that of the plasticity of the mass not being sufficient to admit of its being worked by hand to that degree of tenuity required by commerce, renders a further operation necessary to bring it to the proper dimensions and perfection of form—the crude shape only being obtained upon the wheel, as will be further understood by reference to Fig. 473. Here the workman is represented as in the act of throwing, working with his hands and feet at the same time, and having a skin or apron, *f*, by his side to receive the fragments of slip thrown off in the operation, while the other operator, *g*, is engaged in roughly finishing the piece by means of the iron gauge in his hand. All vessels of an oval or angular shape which cannot be formed by turning, receive their shape by pressure in gypsum moulds, upon the inside of which the prominent parts of the piece are sunk, and *vice versa*.

This manipulation requires that the mass to be formed be of sufficient tractability to be easily introduced into the cavities of the mould by kneading, and that, when pressed, it be of sufficient tenacity as not to bend or yield upon removal. It must, therefore, acquire consistency, and dry in the mould—a condition which renders it absolutely necessary that the moulds be constructed of substances of a porous nature, otherwise the pieces would adhere and lose their shape upon removal. The moulds are, therefore, generally formed of gypsum—plaster of Paris—and sometimes of burned clay, and are of every variety of size and pattern, a complete set of patterns being required for every new design, and for every size of the same pattern. Moulds for plates, dishes, and other shallow articles, consist of only one piece, while for jugs, vases, and more elaborate forms, several pieces or moulds are employed.

The mode of making the moulds for *plates* and *dishes*, and the subsequent operation of *moulding*, are as follows:—Upon a model, *a*—Fig. 476—composed of either metal or gypsum, and turned in relief to

Fig. 475.

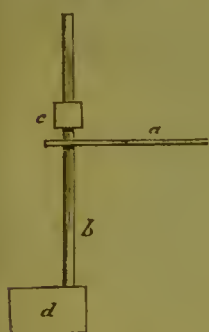


Fig. 476.

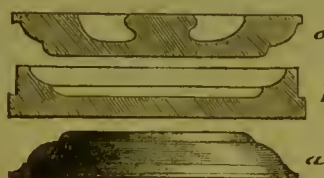


Fig. 477.

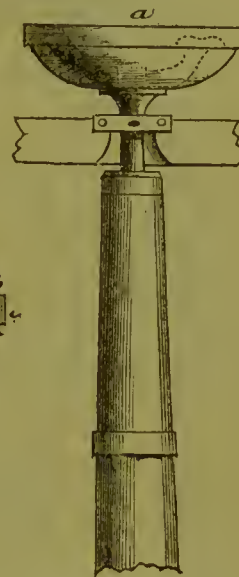
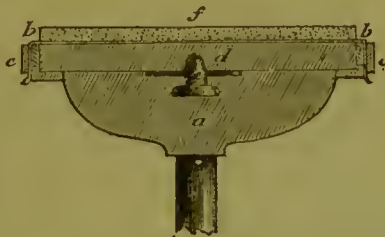
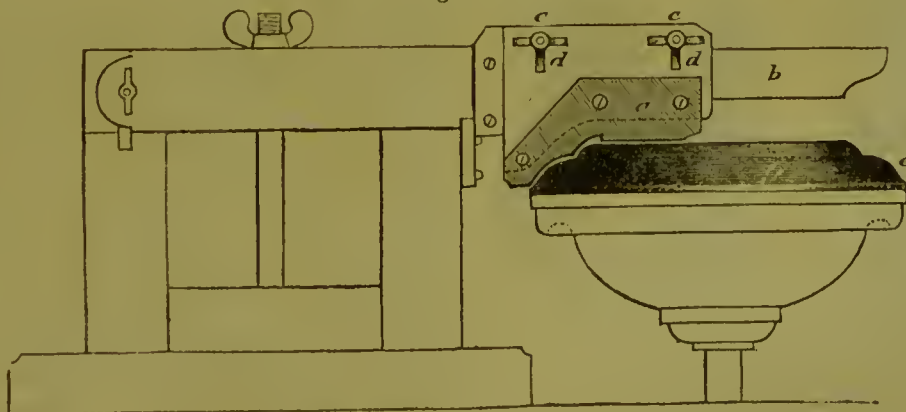


Fig. 478.



correspond with the exact *contour* of the *inner* surface of the plate or dish to be formed a hollow gypsum cast, *b*, is taken. This serves as the matrix, from which, when saturated with oil, innumerable other moulds, *c*, may be taken for use. As gypsum expands in setting about 0.01 of its linear

Fig. 479.



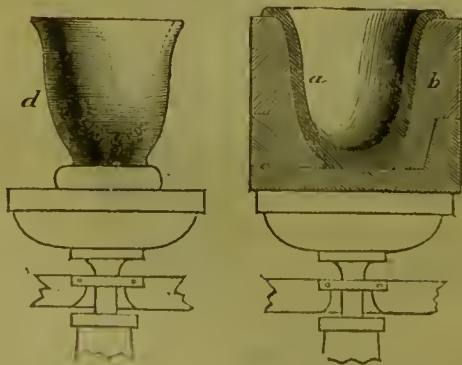
dimension, the original matrix must be made so much smaller. The mould being attached to the revolving

table, *a*—Fig. 477—receives upon its surface the sheet of thin dough, prepared as follows:—The assistant hav-

ing, by means of a wire, separated a piece of dough from the mass, hands it to the thrower, who places it upon the head of the throwing machine, *a*—Fig. 478—over which a piece of wet leather, *b b*, has been previously stretched, after the fashion of a drum, by means of the ring, *c*, the gypsum slab, *d*, fitting on to the socket, *e*. By the revolution of the head, the lump of paste is spread over the surface, and converted into the plate, *f*, which is brought to a uniform thickness by a gauge. It is now removed by means of the leather to the plaster mould, *c*, fixed upon another wheel, and pressed on to it during rotation by a sponge dipped and moistened in *slip*. In this manner the interior form is given to the plate, the outer surface, *e*, being finished off by the profile, *a*—Fig. 479—pressed upon it during its revolution. This profile, formed of a thin piece of brass plate, is mounted upon a carrier or slide, *b*, the adjustment being arranged by serews, *c c*, passing through the holes, *d d*. The excess of paste that extends beyond the proper outline is turned off, and the plate left in a finished state. The maker's name being impressed, the mould, with the plate upon it, is then conveyed to the drying chamber and placed upon a shelf, where it remains till sufficiently hardened to bear removal. In the meantime the operation at the lathe proceeds with other moulds.

In the process of drying, the gradual evaporation of the water contained in the paste brings the solid particles closer together in proportion as the moisture disappears. A consequent shrinking or diminution of volume takes place in the mass, the proper proportions remaining unchanged when the shrinking and desiccation have been uniform throughout; but, if this be not properly effected, distortion is the result. For this reason the pieces after they leave the lathe cannot be dried in a stove or current of air, or even by exposing them to the sun; for by such means they are desiccated only upon the outside, while the interior still contains a sufficient quantity of moisture to cause them to split with a kind of explosion in the furnace. They are, therefore, carefully stowed away in the shade upon wooden shelves, until no more moisture can be evaporated from them.

Fig. 480.



Sometimes the inner surface only of the ware is formed by the hand, the paste, *a*—Fig. 480—being pressed against the mould, *b c*, during its rotation, forming the vessel, *d*; the sheets of paste considerably thicker

than the sides of the future vessel being prepared by rolling on a moistened gypsum slab, *a*, under a wooden roller, *b*—Fig. 481. When, from the elegance or complication of form, the admission of the hand into the mould is impossible, it has been stated that double

Fig. 481.



moulds are used. These are shown in Fig. 482, the paste, *a*, being first laid upon the solid form, *A*, and turned over into the mould, *b*, the interior mould being

Fig. 482



furnished with cavities, *d d*, for more easy removal. Fig. 483 represents the operation of moulding and finishing the additional pieces, such as the spout, handle, &c. *cetera*. The thin sheet of paste, *a*, prepared by rolling at *A*, is carried to the moulder, *B*, who, pressing with a damp sponge, makes the paste adhere to the mould, *b*. The latter is placed upon a circular plaster frame, *c*, mounted upon the iron axis, *d*, which can be revolved at pleasure by the hand of the workman. A further stage is shown at *C*, while the workman, *D*, is moulding a handle, *e*, for the sugar basin, *f*, removing the roughness, and filling up all cavities left by the moulding.

The porcelain paste, from the nature of its ingredients, is exceedingly susceptible to injuries from the least inequality of pressure in the moulding. injuries which are only made apparent at a period of the manufacture when it is too late to rectify them. The principal cause of these is the difference in shrinking during the drying and firing of the parts which have been subjected to different degrees of pressure. These defects are not so apparent when slight pressure only is applied, and may be easily avoided in the ordinary process of moulding; but when the pressure is increased and applied more unequally, they become so marked and unsightly as to render the article useless. Moulding presses are, therefore, only used for objects of small dimensions, in which perceptible differences in the consistency of the mass cannot occur; for larger vessels they are almost

entirely discarded in the manufacture of porcelain. Even when the greatest care is taken in manufacturing the plate upon the mould, faults will occur; the bottom of the piece, instead of presenting an even surface,

Fig. 483.



will often fall away, as represented in Fig. 484, at *d*—a defect very fatal to the beauty of the subsequent processes of decorating and gilding—and the diameter and thickness will be variable at different places. Some

Fig. 484.

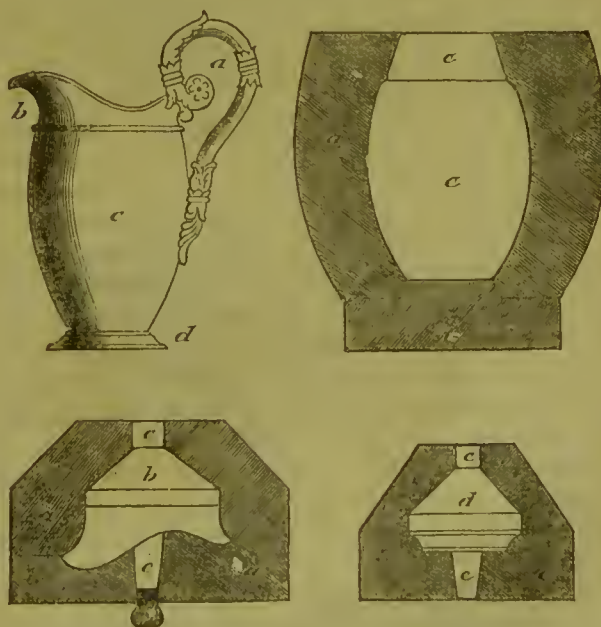


of these faults may be traced to the inequality of dampness in the surface of the mould, but generally to the unequal consistency of the mass used. To prevent loss also in the drying process, it is very necessary that all air be removed from the surface of the paste, as the presence of any particles of air, however minute, is sufficient to cause the splitting of the piece. If the plaster composing the mould also be not perfectly homogeneous and equally dense in all its parts, the absorption of moisture will be very irregular, causing a corresponding inequality in the separation of the paste from its surface.

When a dry gypsum mould is dipped in water, a certain absorption by capillary attraction takes place, the pores becoming filled; and should it happen that the water in which it was dipped held in suspension any particle of clay or other muddy substance, a kind of filtration occurs, the clay being left upon the surface of the gypsum, where it conglomerates and sets, the thickness of this deposit depending upon the duration of the operation, the massiveness and absorbing powers of the mould, the nature of the substance, and dilution of the paste. A very plastic material and pure clay soon form an impenetrable crust, which prevents further increase in thickness; but the flux in the porcelain paste, preventing the particles from

coming into too close proximity, admits of absorption taking place through the deposits already formed. For the purposes of casting, the slip is stirred up into a thick but perfectly liquid state, and passed through sieves, that all granular particles and bubbles of air may be separated, the number and nature of the moulds depending upon the form and elaboration of the article required. Thus in the case of the jug—Fig. 484A

Fig. 484A.



—the foot, *d*, body, *c*, neck, *b*, and handle, *a*, are each cast in a separate mould, the prominence of the parts requiring these distinct operations. The neck, *b*, is moulded in an inverted position, *a a* being the sides of the mould, *c* the aperture through which the slip is introduced, and *c* that through which it is withdrawn.

The same manipulation is applied to the moulds for the other portions, which, being closed below, are completely filled with the semifluid slip, and allowed to remain for two or three minutes before the water is rapidly drawn off, leaving a residuum of from one to two lines in thickness round the sides of the mould. The casting for the body, *c*, of the jug proceeds in exactly the same manner, but the mould is emptied by inversion. The various pieces having been removed from the moulds, and cleaned from superfluous paste, are put together and joined while in a moist state, the connection being so perfect that no indication of it is perceptible. The handle is put on afterwards—see *Earthenware*.

In the moulding of a teapot, five moulds are again required—two for the formation of the exterior form, and three for the interior manipulation, the parts being afterwards united together in such a manner as to produce the interior development of the spout and double easing of the sides necessary for strength and utility. The pieces must remain in the moulds, however, for a considerable time before they acquire proper consistency; the operation of moulding, therefore, requires much time and numerous moulds. Many articles likewise, even without appendages, such as a vase with a narrow neck, cannot be cast in one circular piece, which could not be extracted from the mould even by inversion. Such articles can only be made by casting in two halves, to be afterwards joined together.

In casting, the pieces are never perfect or free from blemish, as they leave the moulder, but require often tedious finishing processes, such as *turning*, *retouching*, *ornamenting*, and the adaptation of the separately moulded pieces to each other.

Turning.—Many articles are made much thicker upon the throwing-wheel than they appear when finished, the superabundant mass being turned off in a lathe to give the requisite beauty and uniformity of *contour*. This turning is precisely similar to that practised in the earthenware manufacture—which see—the clay being in such a state as to throw off a connected shaving without either crumbling or adhering to the tool. In this operation the piece is fastened to the gypsum slab of the throwing-lathe, by moistening the bottom, or fixed on to the lathe in a horizontal position by means of an ordinary chuck, as the case may require, ordinary sharp flat knives being used as tools in place of the chisel. One of the chief points in the finishing operation consists in the removal of the edges or seams caused by the penetration of the slip into the joints of the moulds. It is necessary that the seams should be carefully pared away with a knife, as, if removed by pressure only, they appear again after burning.

The casual cracks and indentations have at this stage of the manufacture to be carefully filled up, and all engraved or carved work which requires cutting away with the knife, to be performed. Frequently an ornamental appearance is imparted to the ware in this state by impression upon its surface with the *roulette* or stamp, in the use of which turpentine is applied to prevent adhesion to the paste, the fatty oils

not producing the necessary effect. It has already been stated that such parts as handles, feet, *et cetera*, are formed or moulded separately, and fixed upon the porcelain before firing, but smooth handles of uniform dimensions are often formed by pressure through an aperture of corresponding shape and diameter—see *Earthenware*—while those of more elaborate pretensions are produced by moulding in gypsum moulds. The union of all such parts with the body is effected by sticking them together under very gentle pressure, the two opposing surfaces having been previously roughened and covered with slip. All changes which affect unequally the mass of the vessel and the ornamental parts tend to cause cracks during the drying, and to separate the latter. It is therefore essential that the body and the ornamentation of the vessel be equally dry, and that the surfaces be prepared either by turning or casting in the same manner; also, that all excess of slip, from the increase of moisture it contains, be avoided. The same precautions apply to the joining together of pieces moulded in separate forms, the surfaces of which should be retouched with a sponge or wet cloth.

Firing.—In the operation of firing the true porcelain with the glaze—see *Glaze*—is rendered dense, vitreous, sonorous, and translucent, the glaze being of that nature that it melts at the temperature necessary for the perfect firing of the mass. The waste heat from this process is employed to produce the ware in the state of *biscuit*, or, in other words, for the firing previous to glazing.

On account of the chemical composition of the substance and the refractory nature of the glaze, the greatest possible amount of artificial heat that can be produced is required. This intense heat is the more necessary, as from the white color of the material, the transparency of the glaze, and its softness at high temperatures, it cannot be exposed to the direct action of the flame. Porcelain, like many other kinds of clay wares, is always, therefore, inclosed during firing within clay vessels or *seggars*—see *Earthenware*. This high temperature of the furnace must, for the successful firing of the pieces, be maintained as steady and uniform as possible, otherwise various misfortunes, such as splitting, bending, and fusing, will ensue. To effect this, with the large quantity of materials and the considerable number of seggars fired at once, requires a peculiar arrangement of furnace; as the porcelain goods cannot be brought into direct contact with the fuel, without impeding the draught, and causing a want of regularity in the distribution of the heat throughout the mass. All pottery requires, therefore, to be baked in a reverberatory furnace, in which the fire being kindled upon a separate grate does not come into contact with it. In short, potters' kilns are all reverberatory furnaces, which possess the advantage of surrounding the seggars more completely with flame, and of imparting a more uniform heat than would be practicable were they placed in direct communication with the fuel.

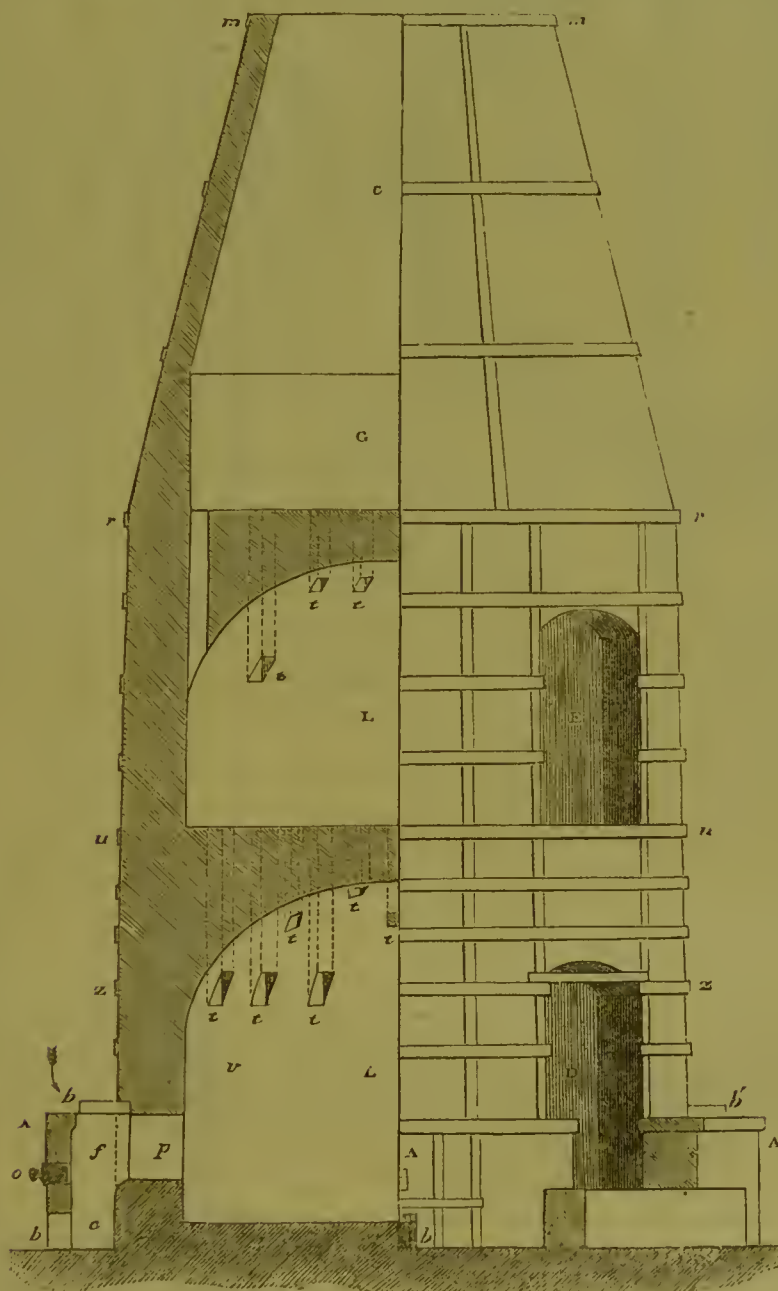
Furnaces.—The porcelain furnace is very similar to the glass furnace, with the exception that the source of heat is dispersed over several grates situated at the

circumference of the base instead of being united into one central fire. It consists, therefore, of a round chamber, on the floor of which the seggars containing the ware are arranged and piled in columns or *bungs*, the flames ascending from a number of wide flues below and around, in connection with the same number of fire-places, so as to circulate between the columns of seggars, filling the whole space, and escaping through different apertures at the top of the chamber into a second room, where they are again employed for heating the *biscuit-ware*. The details of one of these porcelain kilns are shown in Fig. 484B, one-half of which is

in section and the other in elevation, the horizontal section—Fig. 484C—being partly on a line through the fire-bars, and partly through the upper chambers, showing the vent-holes for the circulation of the flame.

The kiln or oven is surrounded by four or five separate fire-grates, A, A, A, A, which first heat the space, L, where the *porcelain* is burnt; then the second chamber, L, where the *biscuit* is baked; and thirdly, the space, G, used either for a similar purpose, or for the firing of the *seggars*—the flames finally escaping through the chimney, c. In the construction of the hearth of the

Fig. 484B.



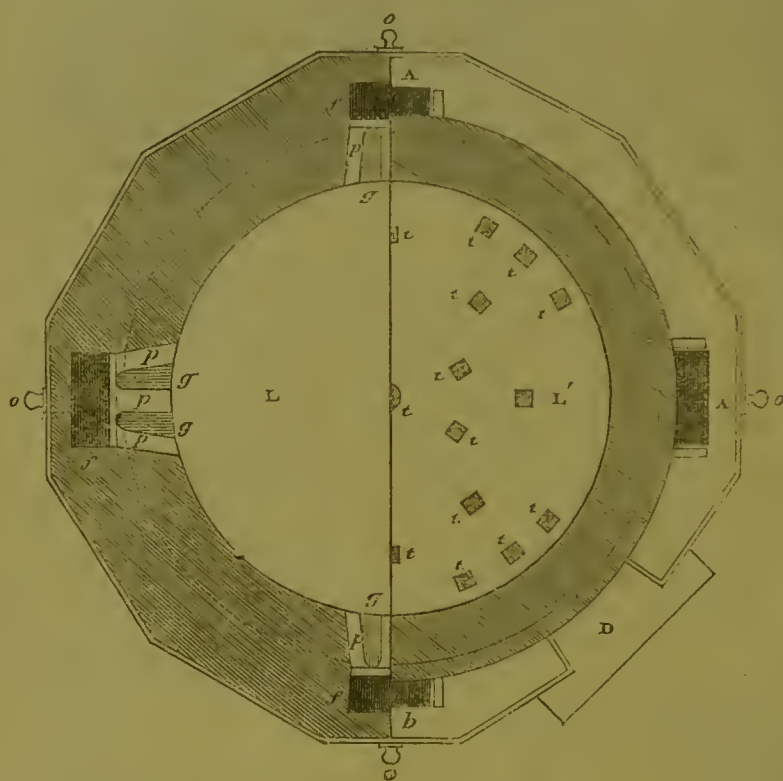
porcelain kiln, the draught is forced to take a direction contrary to that usual in other furnaces. The space, c, being filled with hot charcoal, wood in small billets is introduced through the aperture, b' b', so as completely to fill the space, f. The draught, therefore, in the first instance, assumes a downward direction through b, as indicated by the arrow, and reaching the burning wood between f and c, induces a long flame, which

escapes through the opening, p, into the chamber, L, where combustion is completed. The difference between this arrangement and that of an ordinary fire grate is this, that while in the one case the glowing fuel is brought into direct contact with the external air, and the flame has to pass through the freshly added fuel, in the porcelain furnace the combustion is kept up by air already heated by its passage through the upper

layers of fuel, and the combustion rendered more complete. The hearth of the furnace is composed of a bad conductor of heat, such as bricks; and the velocity of the draught being reduced on entering the wide cham-

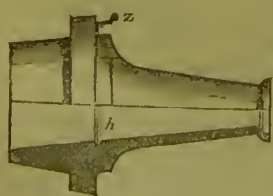
ber, *L*, greater time is allowed for the perfect combustion of the volatile products from the fuel. The small aperture, *o*, employed for the purpose of stirring the fire, is closed with a clay stopper, while the opening, *b*, at the foot of the hearth serves for the removal of ashes, *et cetera*. The regulation of the draught is effected by the lid, *b' b'*, the aperture or flue from which, before entering the furnace, is divided by tongues, *g g*, into the channels, *p p p*, for the better dispersion of the flame. *D* and *E* are doors for the insertion and withdrawal of the goods. In the arched covering of the space, *L*, twenty-five apertures or flues, *t, t*, are left to conduct and spread the flame as it enters the second chamber, *L*, the effect of a single opening in the centre being to draw the flame to one spot. Similar openings, *t, t*, but of half the number, conduct the flame from *L* into the upper chamber, *c*.

Fig. 484c.



For the purpose of examining the progress of the firing, and for the introduction of small samples or *watches* into the seggar nearest the hole, small openings, *v*, are made in the walls of the chamber, *L*. These *watches* consist simply of pieces of bismit covered with glaze, by the appearance of which, and the degree of fusion they undergo, an indication is given as to the state of the porcelain vessels. In order to prevent the access of air into the furnace through the opening, *v*, a tube—Fig. 484d

Fig. 484d.

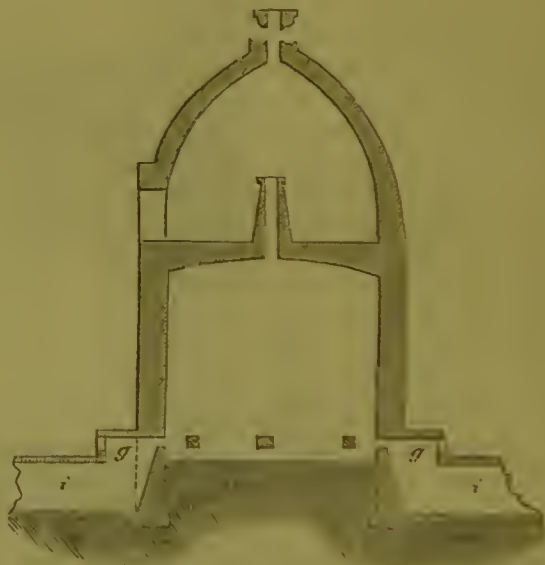


—is introduced from the outside, supplied with an iron damper, *z*, sliding in the frame, *h*, and closed in front by a plate of glass.

These furnaces, averaging about twenty feet in diameter, and forty feet in height, are constructed internally of fire-stone, surrounded by an exterior casing of ordinary brick, the whole being bound together by iron stays or bands, *m, n, r, u, z*. To prevent their cracking or giving way by the great expansion caused by the heat, elastic hooks connect these girders together, and enable them to meet the strain.

An improved modification of this furnace has recently been patented in France by M. VITAL ROUX of Noirlac, with a view to the employment of coal as fuel in the manufacture of true porcelain, without the necessity of reconstructing the entire kiln. It consists of the insertion of a grate at *g*—Fig. 484e—by which the air is allowed access to the fuel from below through the channel, *i*, as well as from above through *g*: the number of fire-places is increased to eight or ten, according to the dimensions of the kiln. It has been found to produce ware much more evenly fired throughout the kiln, while the lining of the furnace and the seggars are less attacked. In consequence also of the draught being greatly increased, and the ash of the coal containing only a very small proportion of alkali compared with that of wood, the clay does not vitrify and destroy to such an extent. The saving in the expense by employing coal instead of wood, is calculated to average from sixteen pounds to sixteen pounds

Fig. 484e.

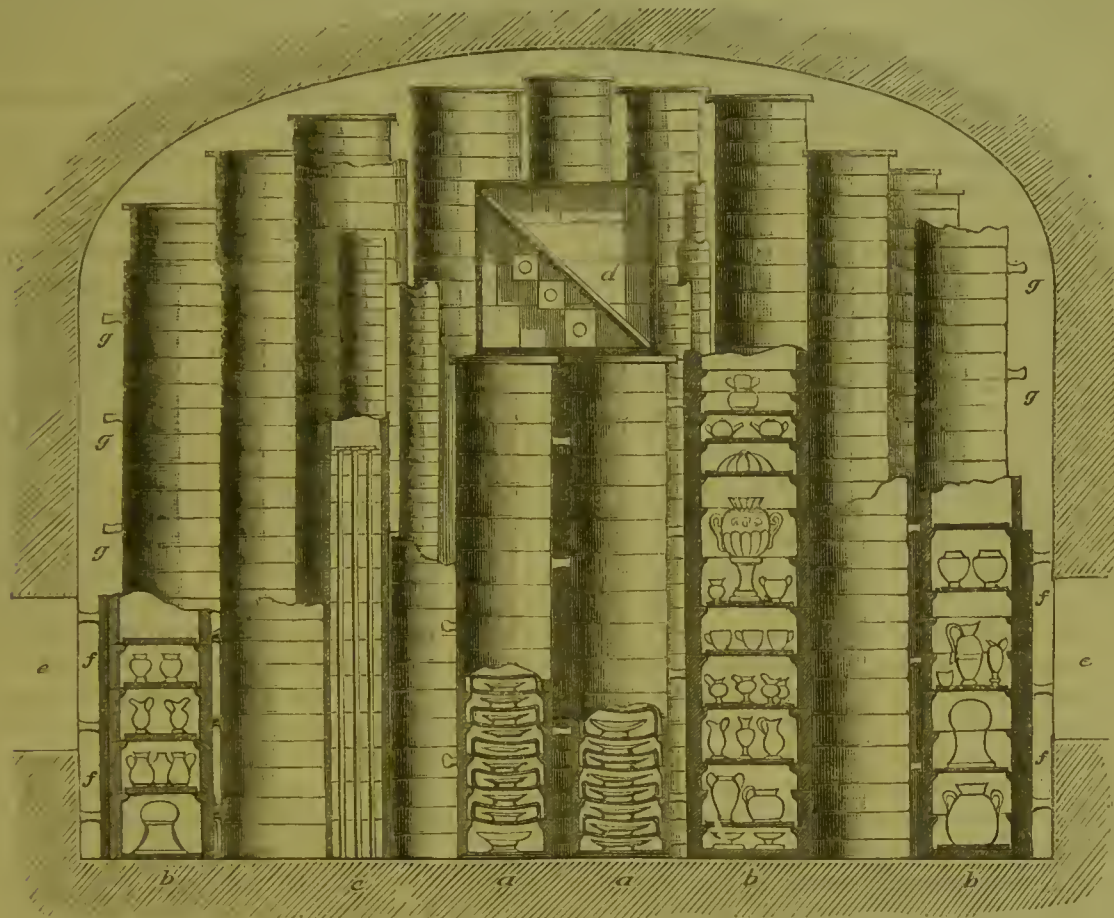


ten shillings for each firing. A vertical section of a porcelain kiln is represented in Fig. 484f; the interior arrangement and piling of the seggars, one upon another, being shown, together with the ordinary contents, such as plates, *a a*, vases and jugs, *b b b*, tubes, *c*, and a porcelain slab at *d*. The partitions which divide the

flame on its entrance to the furnace are shown at *ee*, while *ff* are plates of refractory clay, called fire-guards, which prevent the flames and ashes from coming

into contact with the seggars. *ggg* are props for supporting the seggars. In Germany the furnaces are very similar in construction, but the apertures from one

Fig. 484F.



chamber into the other are only seven in number. They are wider, and furnished with short chimneys, which project it on the upper chamber, L.

The idea of supplying fires to both floors of the furnace, and obtaining the greatest amount of heat, in the hope that the expenditure of fuel in the upper floor would be proportionably less according to the amount of heat derived from the lower one, has been tried at Sèvres, but the results have by no means realized the expectations of the inventors.

Kilns for true porcelain are much more durable than glass furnaces, being free from the destructive action of the volatile alkalis; on an average they last three hundred firings, while in some places they have endured a much longer period. A dry foundation, exerting as little cooling influence as possible, is an important point in their construction.

Fuel.—In regard to choice of fuel, the porcelain manufacture is much more circumscribed than any other industry. It is only those kinds of fuels which burn with a flame that can be employed, and their comparative value depends upon the length and vigor of flame they afford in combustion. Another important requisite in connection with the fuel is, that it should discharge as little dust and ash into the kiln as possible, as this, penetrating between the joints of the seggars, produces black spots upon the surface of the ware. Amongst the varieties of wood in use, preference is given to the light kinds, as poplar, pine-

wood, *et cetera*, cleft into small billets; the effect of which is, that more wood is consumed at once, and a larger flame produced. The wood is not artificially dried, and retains from six to ten per. cent. of moisture. The use of peat has not been found satisfactory as regards the quality of the wares.

Firing.—After the chambers of the furnace have been charged with seggars, the apertures are all closed, and the process of *firing* commences. In this process there are two distinct stages—the first intended only to expel the moisture which may still remain in the vessels, and gradually raise them to a red heat, while the second completes the baking of the porcelain. At the commencement the firemen keep the upper aperture of the fire-hearth closed, the plate *b'*—Fig. 484B—being only removed for an instant as fresh fuel is thrown into the fire; the draught, therefore, enters through the ash-pit, *b*, in the same direction as in an ordinary furnace, producing a smoky, carbonized flame. In this operation the wood is thrown in irregularly in thick billets, crossing each other in various directions, until the furnace is found by examination through the test-holes, *r*, to have attained a cherry-red heat. This being the case, the space, *f*, is filled up to *b'*, with logs of from one to one and a half inches thick, laid parallel, and which are of the same length as the breadth of the hearth; the lower opening, *b*, is then closed. The draught being now reversed, the heat increases, and the smoke entirely disappears,

while the process of *baking* commences, and nothing visible escapes from the chimney but a stream of hot transparent gases. During this process, from the intense draught, the fuel is entirely consumed, all ash being carried away; as after the firing, ash which, from the quantity of wood consumed, should amount to over two hundredweight, does not yield, ash and charcoal together, a cubic foot. Any irregularity in the firing is immediately perceptible, the heat of the furnace diminishing directly on that side where the firing is badly attended to. When any one of the fires is out of order, the red-hot charcoal not being properly consumed, stops the progress of the flames, and causes them to beat back, a fault only remedied by the removal of the charcoal as rapidly as possible. A similar effect in the irregularity of the combustion of the fuel is caused by repairs upon the furnace. At Sèvres, for instance, when one half of a furnace had been newly constructed, it was found that the ware situated upon that side was thoroughly baked two or three hours before the other contents were fired, an old furnace always working more slowly than a new one, and requiring from five to six hours longer to complete the baking. In general the first process of firing occupies half as long as the baking, lasting from seven to eight hours, and the firing from eleven to thirteen. In some instances the two processes, as at Berlin, are nearly the same, the one taking from twelve to fifteen hours, and the firing from seventeen to eighteen. At Sèvres, again, the first is the longer process, occupying from fifteen to eighteen hours, while the baking only takes from ten to twelve hours. The temperature upon the upper floor of the furnace ranges from 30° to 60° of Wedgwood's pyrometer, while that of the lower chamber is from 130° to 160° Wedgwood, the heat of the base of the furnace being some 40° less. The *pyrometer* introduced by WEDGWOOD as a measure of high temperatures can only be employed as affording a useful approximation, and not the accuracy required for scientific purposes; the contraction of the clay under the action of intense heat being the principle upon which its measurements are made. This contraction is variable, even when the same kind of clays are placed side by side in the furnace, and a good pyrometer that shall indicate exactly intense degrees of heat is still a desideratum. As nearly as can be ascertained, the relative value of one degree of heat on the pyrometer, compared with that of the mercurial thermometer, is about 72° of Celsius, or 130° Fahrenheit, the zero of Wedgwood being about 580° Celsius, or 1076° Fahr., so that the greatest degree of heat in the baking will range from 19832° Fahr. to 21632° Fahr.

At Sèvres the average amount of fuel consumed as a mean over twelve operations in a double furnace, with two great fires, was found at first to be seventy-three cubic metres, which gradually diminished at the end of twelve months to fifty-two cubic metres; the mean quantity of porcelain baked during the period was seven hundred and eighty-four kilogrammes, and the seggars required for incasing it fourteen thousand kilogrammes, being in mass eighteen times that of the porcelain. In a kiln—represented at

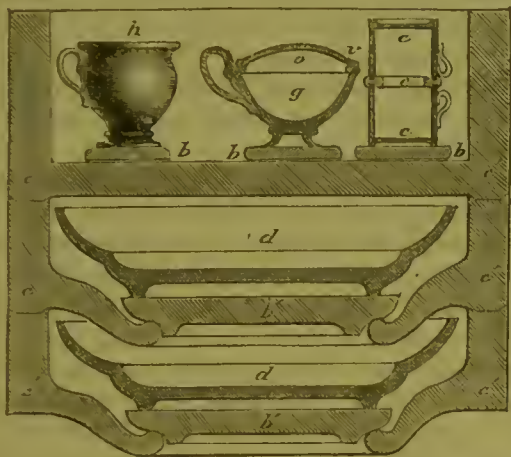
Fig. 484B—the cost of firing one kilogramme of porcelain may be taken as two francs—or one shilling and eightpence; while the cost of a cubic foot of space in the furnace will be one franc one centime—about tenpence. In Vienna, for every firing about seven klafters of wood are used, equal to sixteen and a half stacks, each of one hundred cubic feet, Hebian; in Berlin ten stacks, about seven hundred cubic feet, same measurement.

In consequence of the glaze of porcelain being a true glass, and entering into the mass, the process of annealing requires to be carried out; that is, the material must be cooled slowly in order to prevent it becoming brittle. This is rendered necessary from the circumstance that the particles of the glass, while in a fluid state, have a tendency to arrange themselves in a regular manner, and form crystals; whereas, by the process of cooling suddenly, they are forced to remain in the relative position towards each other which they assumed during the working; and this constrained state is greatest at the surface, where the cooling and contraction have been most rapid, the interior of the mass being less affected. These outer layers are consequently in a state of tension with reference to those in the interior, and a want of uniformity in the results, inducing a tendency to destroy the cohesion of the whole, which the slightest impulse from without will be sufficient to overcome. It is not necessary to employ any separate kiln for this annealing process, the kiln, with its contents, being simply bricked up after firing until it has become sufficiently cool to be emptied. A period of from five to eight days is allowed for the gradual reduction of temperature. In general the kiln is opened the evening before the porcelain is removed, the annealing process being thereby rendered more complete.

Seggars.—The composition of which the *seggars* are composed at Sèvres consists of forty parts plastic clay, sometimes decanted, and sixty parts of ground fragments of old seggars, or an equal quantity of a mixture, containing equal proportions of fragments and crushed quartz sand. At Meissen sixty parts of clay are used to forty parts cement; at Berlin 66.7 clay to 33.3 cement. At Sèvres it has been ascertained that the average duration of the seggars is fifteen firings or more; at Vienna from four to five; and at Berlin only from two to three; in which latter case, the loss occasioned by the seggars becoming useless amounts to nearly thirty dollars, or about four pounds ten shillings at each firing. At Meissen twenty per cent. of the seggars are lost at each firing. These differences result entirely from the local inequalities of the plastic clay, even when obtained from the same deposit, the loss becoming heavier, inasmuch as bad seggars cannot be piled so high in the kiln as good ones. The interior surfaces of the seggars are sometimes glazed, as they have been found to suck up the glaze from the porcelain, exerting a chemical attraction for it by facilitating the volatilization of the potassa, and absorbing it upon their inner surface. It is also of great importance to pay attention to the shrinking of the clay wares upon introducing them into the seggars, as when any obstruction prevents them from shrinking uniformly in their soft-

ened state they become warped and twisted, while the unevenness in the bottom of the seggars renders it necessary often to support the pieces by other means. The form, also, which is given to the seggars is a point of the utmost importance, since the quantity of goods that can be placed in the furnace at the same time depends upon it; and the amount of cost in the firing of each piece is lessened in proportion to the number of seggars that can be properly packed into the

Fig. 484g.



furnace for the same firing. All seggars are, therefore, made in the form of shallow cylinders, except when the particular form of the piece requires it otherwise, and the bottom being flat, each seggar forms the lid of the one placed underneath. Several vessels are placed in one seggar—Fig. 484g—and in order to insure the wares standing upon a perfectly smooth and even surface, small ground plates, *b b b*, are introduced, consisting of the same material as the seggars, and which can be easily taken away and repaired as required. In order to prevent the ware adhering to the plate, the glaze is removed from those parts of the piece

Fig. 484h.

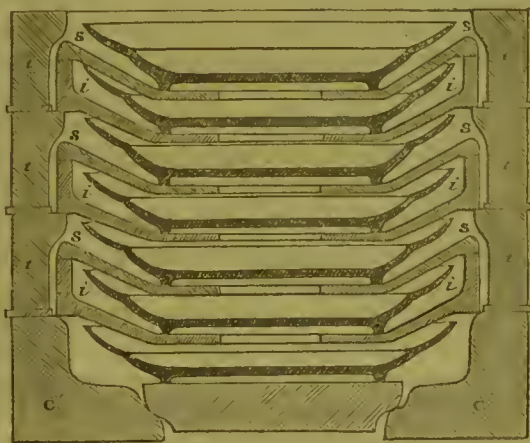


that come into contact with it, and as even those parts which are free from glaze are liable to soften and adhere, sand is interposed to prevent such occurring. Seggars which are intended to support hollow wares,

such as plates, pans, saucers, *et cetera*, are constructed with a curved bottom, which, projecting downwards into the hollow of the vessel situated in the seggar beneath, economizes space; in this way from twenty-nine to thirty plates may be packed into a space which would otherwise have only contained twenty. The bottoms of the seggars are, with this view, constructed in a separate piece, *b b*—Figs. 484g, 484i—which has the advantage of enabling the seggar better to withstand the action of heat without fracture.

A form of seggar was introduced at Sèvres in the year 1839, by REGNIER, which has the advantage of economizing still more the space occupied in the disposition of the pieces, as well as of protecting them from the minute particles of ash carried during the firing through the kiln, and which, as already mentioned, affect the purity of the ware. The principle upon which this seggar is constructed is shown at Fig. 484i—the plate or ware being inclosed in a double casing, an inner and an outer one; and this arrangement requires the two parts to be slightly different in composition. The exterior casing is composed of forty parts of ordinary plastic clay decanted, and sixty parts cement; while the mixture for the interior seggar contains twenty parts ordinary plastic clay decanted, twenty parts of the best plastic clay, thirty parts cement, and thirty parts crushed quartz sand. The outer seggar, *t t*, con-

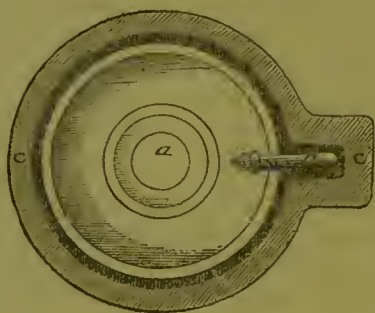
Fig. 484i.



sists only of a hollow ring with a projecting ledge upon the interior of the upper edge to support the plates in their respective seggars, *i i* and *s s s*, which together form one closed vessel, the rim of the lower one, *i*, forming the sides. One plate being inclosed in each of these chambers, a second one is supported between each pair of seggars, the lowest chamber of the series being of necessity formed as at *c' c'*. In this manner from fifty-one to fifty-two plates can be fired in a space that was occupied by from twenty-nine to thirty, with the construction shown at *c c*, and by only twenty when the seggars had flat bottoms, as at *Λ Λ*. This economy of space, amounting to seventy-five per cent. in the height, is reduced to forty-five or even twenty-five per cent. with wares of a less flat outline; the cost of firing one hundred plates upon the new method being two pounds seventeen shillings against four pounds eight shillings as formerly, or fully thirty-six per cent. less. Some

wares, on account of their undulated and varied form are apt to become distorted in the firing, and, therefore, require supports to keep them straight. Thus the two rings, *c c*—Fig. 491—placed one above the other, are separated by the ring, *c*, round which a groove is run at the top and bottom to receive the edge of each cup. The cup, *g*, is furnished with a lid, *o*, which does not belong to it, but is only employed for the purpose of retaining the edge in a perfectly true and circular form. The rim, *v*, of this lid is conical to enable it to rise in proportion as shrinkage takes place in the vessel. To enable vessels of larger size having handles to be fired, the seggar, *c c*—Fig. 484k—is formed with a prominent part for the support of the handle.

Fig. 484k.



When all the seggars are properly arranged and safely piled in the furnace, the joints being secured to protect the glaze from particles of falling dust, the firing is proceeded with, and here great care is necessary to insure that all the articles in the kiln receive the proper degree of heat—too much heat causing a partial fusion, and too little leaving them incompletely burnt. Although the mode of building the kilns insures a tolerably uniform distribution of heat throughout the mass, all parts are not equally hot, these immediately in front of the stoke-holes being much more intensely heated than such as are situated between them. At different heights also a different temperature is attained, the heat being less intense immediately at the bottom, while the greatest intensity is acquired about the middle, diminishing again as it proceeds towards the top.

The piling of the seggars in columns or bungs in the furnace requires great experience and caution on account of the very narrow base they rest upon compared with their height. By the contraction or expansion in the separate pieces an alteration in the centre of gravity will sometimes occur, affecting the stability of the structure so much as often to bring down the entire column, and even those in proximity to it, reducing the whole to a mass of fragments. Frequently a break down of this kind arises from the fracture of a lower seggar unequal to support the weight of the superincumbent mass. The lower seggars require, therefore, to be made stronger and the height of the column to be reduced as at Berlin, in proportion as the quality of the seggars deteriorates by repeated firing. Care must also be taken to place the more massive wares in the centre of the furnace where the heat is greatest, and the thinner and more easily

distorted articles in less heated parts. In order to protect the seggars immediately in front of the furnaces from the too intense heat, hollow semicylindrical screens of clay, *ff*, are employed—Fig. 499. The tendency of the column of seggars to lean and tumble over is counteracted by the insertion of clay between each pair, and the stability of the mass is further insured by the support of broken pieces of seggars, a space of from two to four inches being left between the columns for the free circulation of the flame. In order to prevent the lowest seggars of the tiers from uniting with the floor of the furnace by fusion with the ash mechanically carried with the flame into the furnace, a layer of sand is interposed. Those seggars intended to receive the tests, and which have corresponding apertures in them are placed opposite to the small watch-holes of the furnace.

After firing the wares are removed from the seggars, and the sand which may have attached itself to the bottom, where they rested on the seggars, is ground off by a piece of sandstone or some soft artificial substance, used as a kind of file; while those articles which have been spoilt by bending are assorted and placed aside. This warpage of the ware is sometimes of considerable amount; at Vienna, for example, only three plates out of four come perfect and sound from the firing. Even in the so-called perfect ware there is always something to correct—such as dark points caused by the adherence of minute grains or splinters that have separated from the seggars; or a deficiency of glaze upon the parts which have been in contact with the supports, causing them to appear dull and rough, with a total absence of lustre, and which can never be kept so clean as the glazed portions. When this occurs at the bottom, it is of much less consequence than if on the edges. Such parts are re-glazed afterwards by means of a brush, and exposed a second time to the furnace—an operation of equal risk and expense with the first firing. Sometimes an easily fusible lead glaze is burnt upon these parts in a muffle, but this never acquires the degree of hardness which characterizes true porcelain. For these reasons the inequalities are now commonly removed by a grinding wheel, and the edges and such portions polished finally with tin-ashes, a plan which admits of greater scope in placing the vessels in the furnace and omitting to glaze them in different parts, and one also by which the best ground for gilding is obtained.

The qualities which distinguish porcelain from other wares are its pure milk-white color and entire absence of porosity, together with the very intimate union of the glaze with the mass, and its indestructibility when exposed to sudden changes of temperature. This entirely depends upon the liquefaction of the glaze occurring simultaneously with the complete firing of the ware, and both being nearly equally expansible by heat; the similarity of constitution in the flux and the glaze exerts the greatest influence in this last particular. The *shrinking* which porcelain undergoes, in common with all other wares, is the most important change that takes place, and one which varies with the least alteration in the quality of the body; but which may always be calculated from its remaining constant in mixtures

constituting the same body; the lineal contraction, or shortening in one direction, being on an average thirteen per cent., but sometimes falling as low as seven, and at others extending to seventeen per cent., while the contraction in volume amounts to thirty-nine per cent. on an average. A fourth of this contraction occurs during the first process of firing, and the remaining three-fourths during the subsequent baking of the mass. It may be accounted for in two ways—the evolution of all moisture, and the incipient fusion of the mass during firing. The amount of contraction will vary, therefore, according to the mode in which the mass was formed, the pressure it was subjected to, and the moisture it contains; the shrinkage being least in pressed objects, increasing in those formed in moulds, still greater when the formation of the ware has been on the

throwing wheel, and greatest of all in such as have been cast in moulds. These facts explain why those portions of the ware which have been subjected to less pressure, project after firing beyond such as have been more forcibly pressed. The density of porcelain, and consequently its specific gravity, increases as its volume is diminished; the specific gravity of the dry mass, after the first firing, being 2.305, which after baking is increased to 2.478. This applies to the mass as a whole, and includes the pores. The result is different, however, when its porosity is destroyed, and its specific gravity is taken in the state of fine powder; it is then found to diminish with the increase of temperature to which the mass has been exposed, and the amount of contraction it has undergone—see CLAY. This has been found by experiment as follows, in specimens of—

		Specific gravity.	
		G. Roso.	Malaguti.
Once heated porcelain,.....	Adhering to the tongue,	2.613	2.619
After three hours' baking,	Adhering to the tongue,	2.589	2.440 half baked.
After four hours' baking,	Adhering to the tongue,	2.566	
After nine hours' baking,	No longer adhesive,	2.452	2.242 thoroughly baked.

It follows from these results that the cubic foot of really solid matter, weighing eighty-two pounds, becomes reduced to seventy pounds; and this is accounted for, first, from the fact that nearly all bodies are rendered specifically lighter by their transition from the crystalline to the melted vitreous state, as is the case with the felspar employed in the manufactory at Berlin, the specific gravity of which is 2.592, but is reduced after fusion to 2.384. The specific gravity of the kaolin is likewise diminished in this manner from 2.633 to 2.562. In the second place, the expansion may also arise from a partial chemical reaction of the

ingredients—a fact very probable from the specific gravity of the mass not corresponding with the mean specific gravity of the component parts. The separate particles of the porcelain become, therefore, permanently expanded during baking, but, at the same time, are brought into closer proximity with each other, and goods that have been once heated are not altered in weight by being thoroughly baked. The contraction of the mass composing the seggars is very much less, and often imperceptible.

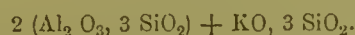
The following analyses of different specimens of porcelain may be given:—

Place of Manufacture	Silica.	Alumina	Potassa.	Protoxide of iron.	Magnesia.	Lime.	Analyst.
China vase,	70.5	20.7	6.0	0.08	0.01	0.05	—
China plate,	63.5	28.5	5.0	0.08	trace	0.06	—
Berlin,	66.6	28.0	3.4	0.70	0.6	0.3	Laurent.
Vienna, 1806,	61.5	31.6	2.2	0.80	1.4	1.8	"
Meissen,	57.7	36.0	5.2	0.80	traces	0.3	"
Paris,	58.0	34.5	3.0	—	—	4.5	Laurent and Malaguti.

THE GLAZE.—At Sèvres the glaze is composed of the pegmatite from St. Yriex, which is felspar, incorporated with a certain proportion of quartz. Although the proportions of these two constituents may vary considerably in small pieces, this ceases to be the case in the enormous mass prepared at the same time at Sèvres, as shown by the following table:—

Component parts of the glaze.	1836.	1839.	1839.	1841.	1842.
	Berthier.	A. Laurent.	Malaguti.	Marignac.	Salvetat.
Silica,	73.0	74.0	73.4	74.6	74.3
Alumina,	16.2	15.6	15.7	16.0	18.3
Potassa,	8.4	6.6	7.4	8.1	6.5
Lime,	—	0.4	1.9	1.2	0.4
Magnesia, ...	—	0.3	0.3	—	0.2
Loss by water, ..	0.6	—	1.3	—	0.3
Loss,	1.8	0.1	—	0.1	—
	100.0	100.0	100.0	100.0	100.0

The mean of these analyses corresponds with the formula—



In some places, as at Berlin, Nymphenburg, and Meissen, the glaze is composed of kaolin, gypsum, and broken porcelain, equivalent to a gloss containing alumina and lime, with no more potassa than the small quantity contained in the felspar of the kaolin and broken porcelain. In the beauty of the porcelain, everything depends upon the proper fusibility of the glaze, as when too difficult of fusion it does not become fluid enough to form a smooth and even surface, but appears wavy; while, should it be too easily fused, it becomes liquid before the paste is sufficiently baked, and when the latter is still so porous as to suck in the glaze, in consequence of which the ware afterwards presents a rough and dry appearance. As has been before stated, all the ingredients of the glaze require to be

finely pulverized, decanted, and mixed in the same manner as the paste composing the ware. The operation of putting on the glaze can only be accomplished in a rapid and uniform manner by dipping the pieces into a vessel containing the glaze in the form of slip suspended in water; and as, in this operation, the wares, if simply dried, would not only be liable to bend in handling, but would also absorb the water too slowly, they are previously fired to a certain extent, in which state they are called *biscuit*, in order to counteract this tendency—see *Firing*—and after having received this first firing, they absorb, when dipped into the mixture, a certain quantity of water, leaving the suspended glaze attached to the surface. The quantity and thickness of the coating will depend, therefore, very much upon the porosity and massiveness of the vessel immersed, the amount of glaze slip held in suspension, the length of time the vessel is kept in the liquid, and the dryness of the biscuit previous to dipping—circumstances all more or less tending to render the deposit of glaze unequal, and only guarded against by proper care in the preparation of the biscuit, and reduction of the slip to a proper consistency. In general, a very short immersion, varying from twenty to forty seconds, is sufficient; the more rapidly that the operation is performed, the more uniform will be the absorption of the liquid; and to insure this as far as possible, that portion of the ware which was first dipped into the glaze is always first removed. After the dipping process has taken place, the part of the piece held by the workman is coated with glaze by the aid of a brush, and the glaze is removed from those parts of the vessel which, coming in contact with the seegar in the operation of firing, might cause adherence by its fusion.

The process of dipping the *biscuit* wares into the glaze tub is shown at Fig. 484L. The operator, A, holding the plate with the right hand by the rim, plunges it into the liquid, his left hand receiving it at the opposite side upon emersion; the workman, B, dips it again vertically, holding it so as to allow the excess of glaze to run off; the assistant, C, removes the glaze from the bottom of the plate to prevent it adhering to the support on which it is placed for the purpose of firing. As the pieces are taken out of the trough they are placed upon the shelf, *g*, the sieve, *t*, being employed to separate the froth or other impurities floating upon the surface of the glaze. The *blunger*, *r*, is for the purpose of agitating the glaze and maintaining it at a proper degree of consistency; *b* is a vessel containing vinegar, used for mixing amongst the glaze from time to time; and *c* is a small cup containing glaze and a brush for retouching defective portions wherever the glaze is uneven or coated too thinly. It is obvious, that if

during the operation of glazing, the mixture is allowed to settle down, the coating of glaze in the dipping process will be unequal. The liquid is, therefore, stirred from time to time, and some substances mixed with it

Fig. 484L.



to prevent the slip from being deposited. Vinegar exerts a most remarkable effect in this particular: for instance, glaze in water at a temperature of 65° requires only four hours and twenty minutes to separate; in water, at a temperature of 140° , three hours; while in water containing three-seventh parts of vinegar it requires six hours; and in water with one twenty-second part of gum-arabic eight hours, under similar circumstances. When a thinner coating of glaze is required upon any particular part of the ware, that part is moistened previous to immersion, while places desired to be entirely free from glaze are coated with a mixture of wax and tallow. When necessary, a portion of the glaze may be removed by the application of the brush, or the whole by scraping with a knife.

Decoration of Porcelain—see also *Earthenware*. From the nature of the surface of porcelain being that of a true glass, it is the best adapted of all clay wares for the purposes of ornamentation with pigments and metallic lustres; the art being analogous in fact to glass-painting, with the difference that the coloring is solely adapted for reflection and not for effect by transmitted light. All the pigments, therefore, are colored glasses, which acquire their lustre and adhesion to the mass by fusion, and consist of a *flux*, with the addition of a *coloring* ingredient, generally a metallic oxide; such tints as will not withstand the agency of heat being, of course, excluded. Some of the metallic combinations in use for producing the various hues are given below:—

1. Yellow, Oxide of titanium.
2. Yellow, { Chromate of lead and chromate of baryta.
3. Yellow—different tints, Oxide of antimony.
4. Orange-yellow, black, Oxide of uranium.
5. Yellow tints—red, brown, violet, grey, sepia, black, } Oxide of iron.

6. *Violet, brown, black*,.....Oxide of manganese.
7. *Blue, grey, black*,.....Oxide of cobalt.
8. *Brown*,.....Protochromate of iron.
9. *Beautiful black*,.....Sesquioxide of iridium.
10. *As an addition to carmine* } Chloride of silver.
- and purple*,..... }
11. *Purple*,.....Purple of cassius.
12. *Red*,.....Suboxide of copper.
13. *Green*,.....Oxide of copper.
14. *Green*,.....Oxide of chromium.

Transparent and opaque colors or enamels are used with equal effect upon a white and almost opaque ground, such as porcelain. Transparent colors are rendered *opaque* by the addition of oxide of tin; and oxide of zinc is used for *enlivening* the different tints, a property peculiar to the oxide of that metal, and the effect of which is greatly enhanced by the fact that it imparts no color to the glass; it also improves the sulphur-yellow colors of the oxide of antimony.

As the property of communicating any desired color to glass is confined within certain limits of temperature, beyond which the tint varies, or is altogether destroyed, a certain classification of the colors becomes necessary, according to the reaction of the temperature upon their constituents. They are, therefore, divided into such as have the power of withstanding the most intense heat of the firing kiln, and which can be burnt in with the glaze—termed *refractory* colors, and those which afford no color at such temperatures, on account of the volatilization, or only a very imperfect tint—designated *muffle* colors. The latter require to be applied to the wares after the process of glazing has been completed, and afterwards fixed in a small furnace called the *muffle*, shown at Fig. 484M—and at a temperature far below the fusing point of the glaze or body of the ware, otherwise they would run and penetrate into the glaze. *Muffle* colors, being painted upon the ware in *relief*, can be distinguished by touch from the decoration in *refractory* colors, and impair by their projections the lustre and smoothness of the surface, besides being more liable to suffer and wear away by friction. It is worthy of remark also that the firing of *refractory* colors causes no increase in expense, while the burning in the muffle is a constant source of additional expenditure. The refractory colors are—

1. *Blue*, with cobalt.
2. *Green*, with chromium.
3. *Brown*, with oxide of iron, oxide of manganese, and perchromate of iron.
4. *Yellow*, with oxide of titanium.
5. *Black*, with oxide of uranium.

These pigments in the firing generally impart a very intense color, and can be used in very small quantities, which exert no liquefying action on the glaze, or on the mass of the ware. They may either be applied directly to the bisuit ware, or upon the glaze, the silicate of an alkali being used with them as a flux. *Muffle* colors

are incorporated with a great variety of fluxes, the most important of which are—sand or quartz, saltpetre, borax and boracic acid, felspar, potassa, soda, and minium or litharge.

Gilding is executed on porcelain in the usual manner, the gold being prepared in a pulverized form, and pre-

Fig. 484M.



cipitated from its solution in nitrohydrochloric acid by protosulphate of iron. The brown powder thus obtained is washed, dried, mixed with about one-tenth of oxide of bismuth, and rubbed up with thickened oil of turpentine. This gold mixture is then applied with the brush and fired in the usual manner, when the oxide of bismuth forms a flux with the surface of the glaze, and the gold becomes firmly attached. It has a dull yellow appearance upon leaving the *muffle*, and requires to be burnished with an agate to restore its metallic lustre. *Platinum Black*, or *Platinum Sponge*, is applied in precisely the same manner as the metallic gold. A preparation of gold, held in complete solution by oil of turpentine, is used for gilding at Meissen. It is not so durable, however, as that obtained by the ordinary process.

As a certain amount of heat is necessary in the muffle for the successful firing of the more fusible colors and gilded ware, pyrometrical tests are applied to ascertain the necessary temperature. A very convenient test is afforded by the variation of color through which the gold purple passes when submitted to a gradually increased temperature, six gradations being marked by the porcelain painters, corresponding to the six most important changes in temperature. Thus a piece of porcelain painted with the prepared purple of cassius, and exposed to the muffle, gradually becomes—

		Degrees of Fahr.
Of a dirty-brown red color,.....	corresponding to gilding upon colored grounds,.....	1148°
Brick-red,.....	" retouching,.....	1474°
Brick-red, passing into rose, and red on the edges and thinner parts,..		
Rose-color, passing into purple,.....	" easily fusible colors,.....	1652°
Rose-color, passing into violet,.....	" gilding upon glaze,.....	1688°
Rose-color, passing into deep violet,..	" gilding upon plate edges,.....	1742°
Violet has become lighter,.....	" more difficultly fusible colors,.....	
Rose-color has disappeared, and the violet become very pale,.....	" dull gilding,.....	1832°

The *watches* introduced into the muffle for the purpose of ascertaining the temperature, are covered both with gold and color, in order to ascertain the degree of heat at which the gold becomes attached without altering the tints of the hues. Painted porcelain generally requires retouching and passing through the muffle two or three times, the results of the first firing always being more or less imperfect. The principle of the muffle pyrometer used at Sèvres depends upon the expansion of a silver rod, which, melting at 2282° — 1000° Celsius—does not register quite up to that temperature. At this manufactory, also, an ingenious method of removing faults in the painting is adopted previously to retouching them. A brush, dipped into liquid hydrofluoric acid, is traced over the parts, which are afterwards washed with water; the etched part appearing perfectly white, and only slightly corroded, is in a very favorable condition for receiving the fresh pigments.

The semitransparent nature of porcelain has been made subservient, within the last few years, to the production of elegant imitations of paintings, and termed *lithophanous* pictures or transparencies, from *λίθος*, stone, and *φαῖνω*, I shine through. The porcelain plates are constructed thicker in some parts than others, according as it is intended to produce greater depth of tint, or otherwise. When a plate thus contrived is held against the light, the thicker portions appear shaded compared with the rest; and if the blending has been arranged with care, representations of exquisite softness and gradation in tints are obtained. The manipulation and firing are, however, attended with considerable difficulty.

Some very interesting and important experiments have been made by BROGNIART and MALAGUTI, with reference to the nature of porcelain, and which also furnish valuable hints connected with its manufacture. Masses of porcelain clay, composed of different suitable materials, and affording the same per centage composition as the porcelain mixture adopted during the last sixty years at Sèvres, 58 silica, 34.5 alumina, 4.5 lime, and 3 potassa—were submitted to the different processes of manufacture with the following results:—

When chemically pure substances were taken, such as—1, Precipitated silica, in part fritted with the proper quantity of potassa; 2, alumina, perfectly free from potassa, prepared by precipitation from alun; 3, pure lime instead of chalk—the mass melted at the lowest degree of heat in the kiln to a spotted enamel.

Another specimen of the same mixture, with less frit, contracted in the biscuit oven eighteen per cent., and in the firing twenty-eight per cent.

When the kaolin was replaced by fire-clay, and the potassa was added, having been previously fritted with silica, a mass was produced which, after exposure to

the biscuit fire, exhibited the fluxed appearance of ordinary stoneware, and which when fired could scarcely be termed porcelain from its spotted nature and slight degree of transparency.

By using a similar mixture of plastic clay, in which a proportion of leucite, instead of the necessary amount of potassa, was present, a well-glazed porcelain was obtained, though somewhat spotted. When lime was employed in place of chalk, or the quartz was replaced by flint, no alteration in the properties of the normal mass was observed.

These experiments show that it is by no means a matter of indifference of what materials or of what minerals the elements of the mass are composed, even though its relative proportions remain the same.

Fig. 481a.



Parian or *Carrara Biscuit Ware*, introduced some fourteen or fifteen years ago, is the finest description of biscuit made, and differing only from porcelain by the employment of a soft, more fusible felspar in place of Cornish-stone. In effect, statuettes and other objects made of this ware, present a great similarity of appearance with the beautiful marbles after which it is named. The general introduction of this art was due to a suggestion of the great sculptor JOHN GIBSON, to reproduce his *Narcissus* as a statuette in the statuary porcelain, and was first successfully carried out by the firm of COPELAND and GARRETT, the eminent manufacturers of Stoke-upon-Trent, under the artistic direction of Mr. THOMAS BATTAM, a gentleman well known as the director of the *Ceramic Court* at the Crystal Palace. The perfection to which the manufacture is now carried, is evidenced by the grace and beauty of outline of the

works both of ancient and modern art reproduced in this material by the Messrs. COPELAND, MINTON, WEDGWOOD, KERR and BINNS, RIDGWAY, MAYER, and other eminent potters. Outlines of two of these groups—the production of Messrs. COPELAND and GARRETT—are annexed; Narcissus, by GIBSON—Fig. 484N—the first Parian statuette ever produced, and executed for the Art Union of London; and the second, a reduction of Sabrina, by J. C. MARSHALL, —Fig. 484O. It is hardly necessary to add, that other eminent sculptors have lent their aid in the development of beautiful models in this material, so nearly approaching the true marble. In the *Parian* body the agreeable creamy or yellowish-white tint which it possesses is not due to any coloring matter mixed up with the ingredients, but is owing to the presence of a small quantity of oxide of iron in the clays and felspar, which during the firing forms with the silicic acid a silicate of sesquioxide of iron, imparting the color. The making of figures with the Parian body requires great care, knowledge, and skill, being cast in different parts, and afterwards united together. The *slip* for this purpose is in a liquid state, the deposit

tained in the slip, the mass contracts in the firing process no less than one-fourth of its bulk. Some of the ingredients composing the Parian bodies are given below:—

No. 1.—FRIT.

Well washed Lynn or Isle of Wight sand,....	80 pounds.
Felspar,	35 "
Cornish stone,	15 "
Pearlash,	12 "

The whole mixed together with water, and fired in flinted seggars, at the earthenware heat.

MASS.

Frit,	50
Felspar,	130
China clay,	130
Fine powdered glass,	20

These ingredients being all well ground together.

No. 2.—FRIT, made as before.

MASS.

Frit,	50
Felspar,	35
Felspar calcined at a gloss heat,	35
China clay,	75
Bone,	75
Powdered glass,	15

The above for statuettes and finer productions.

No. 3.

Felspar,	350
China clay,	200
Flint,	25

No. 4.

Felspar,	300
China clay,	180

No. 5.

Felspar,	200
Cornish stone,	100
China clay,	150

For vases, small figures, jugs, *et cetera*.

The beautiful perforations and network first introduced into porcelain statuary manufacture at Coalport, such as lace, drapery, *et cetera*, are made by a very ingenious and at the same time simple process, being a kind of incrustation of the original fabric, which, dipped into the slip, is afterwards allowed to dry, a deposit of slip being everywhere formed upon it. The subsequent process of firing destroys the original tissue inside.

In practice the process may be described as follows:—Upon a gypsum slab, over the surface of which a film of the fluid slip has been brushed, the piece of net is evenly spread out and a second coating of slip afterwards laid over the whole. The porosity of the gypsum absorbing the water leaves only the clay in a thin film surrounding the fibres of the net, which, when lifted, is wrapt around the statuette to be decorated, and placed in the oven. If it were not for this absorbing of the gypsum, the minute interstices of the lace would become filled up with the liquid and present a solid part when fired.

STONEWARE.—Under this denomination two varieties of claywares may be classed—*fine stoneware* and *ordinary stoneware*—differing essentially from each other in the nature of their constituents. The chief

Fig. 484O.



in the mould being allowed time to harden before removal; after which those parts which, from the softness and yielding of the mass might sink, are supported by props. From the large proportion of moisture con-

substances used in the manufacture of stoneware are the layers of pipe and plastic clay which lie above the chalk, and generally abound in the coal formations. The plastic clays, like the varieties of kaolin, must be considered as definite combinations of silica and alumina, probably $2 \text{ Al}_2 \text{ O}_3, 3 \text{ SiO}_2$, with water of hydration more or less contaminated with other mineral substances by mechanical agency. A distinguishing characteristic of these clays is the small quantity present of those mixtures of bases which tend to promote easy fusibility, the greater portion of the plastic clays being infusible. On analysis, these clays show from 1 to 4 per cent. of oxide of iron, from 0.5 to 2 per cent. of lime, a rather smaller amount of magnesia, and from 0.5 to 1 per cent. of potassa, ingredients not necessarily all present at the same time. In color the clays vary; passing from the most general one, white, to whitish-grey, or into greenish, rose color, or violet; at other times bluish-black or black. At a temperature of 212° only a portion of the water they contain is expelled; the other portion, amounting to 6.12 or 18 per cent., being held in chemical combination, can only be completely driven out at a red heat, the temperature at which the clay burns and loses its plasticity. At that temperature a chemical action occurs, the alumina being rendered much more soluble in acids than is the case with fresh clay. Thus, clay when burnt loses 44.3 per cent. of alumina in sulphuric acid, while fresh clay only parted with 23.4.

The plastic clays in general contain little of the undecomposed fragments of rock and coarser ingredients, but sand and finely divided silica are mixed with them in very varied proportions. In the analysis of thirty different varieties at Sèvres, the amount of silica was found to vary from forty-two to seventy per cent., alumina twenty to forty per cent., and of water between six and nineteen per cent., the remainder being oxide of iron, lime, *et cetera*. Plastic clay, after burning, is white or reddish from the presence of oxide of iron, the other colors arising from organic substances being eliminated in the fire.

Fine Stoneware.—The production of this ware is most extensively carried on in England at the potteries, where the manufacture has attained the highest degree of perfection. With it may also be included that known as Wedgwood jasper-ware—from its celebrated discoverer—and famous for its unrivalled production of cameos and medallions. As it is manufactured in great quantity and in almost every conceivable form, it will be treated of under *Wedgwood-ware*.

The mass composing fine stoneware is a mixture of plastic clay and a flux of a felspathic nature. The hard texture of plastic clay after burning, and the shrinking it undergoes, cause it to become very fragile, while the application of long and intense heat is necessary to produce that semifusion which is one of the characteristics of the ware. This semifusion is faci-

litated by the addition of the flux, which acts precisely in the same manner as in real porcelain; the external difference between fine stoneware and real porcelain being the almost entire absence of translucency in the former.

Mixture.—The mass composing the body of fine stoneware is more complex than that of common earthenware, and being harder and more brittle after firing than the latter, is distinguished from it by the term *dry body*. It is generally composed of *kaolin*, *plastic clay*, and *Cornish-stone* as a flux. Sometimes the kaolin and sometimes the plastic clay taking the preponderance; but the proportion of the flux generally amounts to fifty per cent. of the whole—a much larger proportion than in the true porcelain body. It is from this circumstance that fine stoneware, when subjected to the heat of a porcelain kiln, melts, and requires therefore a more moderate temperature in baking. The mass is much more plastic than that of true porcelain, a circumstance which enables it to bear a much larger proportion of a poor flux, such as felspar, than the kaolin. Fine stoneware may therefore be considered a substitute for real porcelain, the manufacture being cheaper, from the greater ease and facility with which it is fired, and possessing also the property of non-permeability to liquids.

Some of the proportions in mixing the mass are given below:—

White stoneware bodies for jugs, <i>et cetera</i> .	I.	II.	III.	IV.
Cornish stone,	80	40	160	20
Cornish clay,	20	10	20	10
Blue clay,	40	20	18	18
Flint,	20	—	40	2

with the addition of a little blue cobalt to whiten.

Mortar bodies.	I.	II.	III.	IV.
Cornish stone,	200	90	50	30
Blue clay,	80	80	25	20
China clay,	—	30	20	40
Glass,	—	—	1	—

These separate ingredients are all ground to a fine powder—see *Earthenware*—and mixed together with the greatest care, in order to increase the plasticity of the mass in working.

The wares are formed in a similar manner to that described under *Earthenware* by means of the wheel and lathe, or pressed into plaster of Paris moulds, when the irregularities of the outline render this necessary. Many kinds of this ware are decorated with *basso-reliefs*, the manipulation of which will be found under *Wedgwood jaspers*. These bas-reliefs, from the more binding character of the material, are fixed on to the body with greater facility than is the case with true porcelain. Many varieties of stoneware are composed of a colored mass, care being taken that the metallic oxides used for that purpose are not applied in such quantities as to impart easy fusibility, or endanger the stability of the ware in firing. The ingredients in use for forming certain colors are given below:—

Colored stoneware bodies.

Sage—White stoneware body :—Stain—Oxide of chrome and cobalt.

Drah—White stoneware body :—Stain—Fifteen per cent. common marl, and a little nickel.

Dore—White stoneware body :—Stain—One per cent. manganese with one-fourth part per cent. cobalt.

Other colored bodies being merely modifications, according to the tints required. The after process of

firing the mass is much the same as that described under *Earthenware*.

Wedgwood Jasper-wares.—Amongst this celebrated description of fine stoneware, the manufacture of Mr. WEDGWOOD, may be enumerated those known as *jasper*, *terra-cotta*, *basalt*, *granite*, and *porphyry*; wares which, from the particular composition of their bodies, are capable of receiving the most exquisite degree of finish and delicacy in their manipulation, rivalling in beauty of form and chasteness of outline the art productions of the ancients.

One of the most remarkable of these bodies is the *jasper* or *onyx*, which presents to the eye a white biscuit of a porcellaneous nature, and which has the property of receiving, through its entire mass, by the admixture of metallic oxides, the same colors that those oxides would impart to glass or enamel in a state of fusion. This property, peculiar to itself, renders it applicable in a manner no less pleasing than extraordinary to the production of *cameos*, *portraits*, *vases*, and all subjects which require to be shown in relief, the ground being made of one color, while the raised figures are of the purest, most delicate white.

The composition of this jasper or onyx body may be given as follows, the blue color being imparted by the admixture of oxide of cobalt, in proportions varying from one-third of a part to one part per cent., or more, according to the depth of tint required:—

White jasper bodies.	I.	II.	III.	IV.	V.	VI.
Salphate of barytes, . . .	150	40	30	50	32	160
China clay,	35	—	—	15	10	60
Blue clay,	45	20	12	35	25	90
Flint,	35	—	3	10	8	40
Gypsum,	6	—	—	—	1	8
Cornish stone,	50	20	20	—	7	—
Bone,	—	—	—	25	—	—

The proportion of *stain* being one part of cobalt to from fifty to seventy-five parts of the body, according to the depth of color required. The various other colored jaspers are obtained by the addition of other oxides to the several white bodies.

The *green* jasper is obtained by the admixture of the oxide of chromium.

This jasper body resembles so nearly in appearance the glassy vitreous substance of the ancient gems, that it has become celebrated throughout the world for the beautiful imitations of medallions, cameos, and vases it is capable of producing. It constitutes also the dark-blue ground, with its gem-like surface, of WEDGWOOD'S copy of the Portland vase, a sepulchral urn of great antiquity, discovered in the neighborhood of Rome between the years 1623 and 1644. The careful investigation of this gem of art has pronounced the body of the vase to be formed of a transparent glassy structure of a deep amethystine hue, but which, when viewed by reflection, appears black and opaque, while the raised figures on its surface are white glass, of a sufficiently transparent nature to admit of the blue color of the ground tinting their form through the thinner parts, while the thick possess sufficient opacity to appear of a pure white. The examination both of the ground and bas-reliefs lead to the belief that the blue body of the vase when formed, and still red-hot, was coated all over as far as the bas-reliefs were intended to reach with the white glass, and the handles applied afterwards while in the same red-hot condition—a fact demonstrated by

the intervention of a layer of this white enamel between the body of the vase and the lower extremity of the handles, the upper portions being in direct contact with the vaso itself. The figures seem to have been produced by a subsequent cutting away of this white coating down to the blue ground, after the manner of real cameos.

The extent to which the manufacture of imitative ancient gems was carried in the Wedgwood jasper body was enormous, and is again considerably upon the increase at the present time; the original purity and other pristine qualities being revived at Etruria, the seat of the manufacture, by the energies of Mr. GODFREY WEDGWOOD, the eldest son of the present FRANCIS WEDGWOOD, the descendant of the great JOSIAH WEDGWOOD. This, from the re-discovery, as it were, of the first jasper body, together with the possession of all the original models and moulds designed by FLAXMAN and others, renders it more than probable that the ware will again attain the high standing of former years, and that the mantle of the great WEDGWOOD will once more descend amongst his own people.

Manufacture.—In wares of this description the mass is frequently white, and only covered on the surface with a thin colored coating of the same body, the shrinking properties of the mass not being essentially affected by the addition of small quantities of the metallic oxides. The mass, after formation upon the throwing wheel in the usual manner, receives when sufficiently hardened the proper outline upon the lathe; and if a vase or other similar shape, such rims or fillets are turned as are intended to appear white upon the dark ground in the after manipulations. The piece is then taken into the dipping-room, where it is immersed in a tub containing the colored slip of a consistency approaching thick cream, and receives a thin even film over its whole surface. It is then allowed to harden until it is sufficiently firm to admit of being placed a second time upon the lathe, when a burnisher is run over it to give uniformity and smoothness to the surface; the blue dip, at the same time, being turned off, and exposing those portions intended to appear white, such as mouldings, lines, *et cetera*, produceable on the lathe.

The piece is then taken to the *decorator*, who affixes the various ornamentations intended to complete the design. Taking the vase in one hand, he with a small hair pencil moistens with water that portion of the surface intended to receive the pattern, which is affixed in its proper position by a very gentle pressure of the finger and the aid of a damp sponge; each separate ornament being added in this manner, until the whole decoration is complete. The piece is then sent into the oven to be fired in the usual way.

The ornaments in relief are obtained, like an impression from a seal, by pressure in a mould made of baked clay or plaster of Paris. The moulder sits at a bench with a number of these small moulds before him, a lump of the plastic material forming the body of the ware being placed at his side, and from which, by means of a small spatula, he separates pieces of the clay, and rapidly fills or presses them into three or four of the moulds. This done, he takes the one first

in order, and with the smooth flat end of his tool burnishes over the surface of the mould, removing the surplus clay, and causing the sharp-cutting edge of the die to give a clean sharp outline to the impressed clay, which, yielding slightly to the rubbing process by suction, leaves the mould, and is turned out on a slab for use by the decorator, who has to exercise considerable care and dexterity in preserving the sharp outline of the relief in its application to the ware. In the *original* WEDGWOOD fabrications, so much of the beauty of the piece depending upon this particular, the outlines were sharpened and restored by modellers before the ware was sent into the oven, producing such exquisite embellishments that now, sixty-five years after his death, connoisseurs are eager to purchase them at three times their original price. Those decorations, such as flowers, *et cetera*, which are not capable of receiving their form by pressure in the mould, are modelled by hand separately, and united afterwards piece by piece together. The other bodies of WEDGWOOD, which in composition resemble agate, jasper, porphyry, and other variegated stones of a vitrescent or crystalline fracture, are used largely in the formation of ornamental wares. These bodies are composed of various colored clays, placed in layers to represent when pressed together the several stones they are intended to imitate, care being taken that they shall not so amalgamate as to destroy the beauty of the imitation.

The *Basalt* or black Egyptian biscuit, so called from its resembling basalt in appearance and color, forms the mass from which the most esteemed forms of ancient Egyptian art are modelled, and which is enriched with bassi-relievi both in red and white; many articles

of domestic requirements, such as tea-pots, milk jugs, ink-stands, *et cetera*, are moulded in the same style from this mass. In composition it may be given as follows:—

Basalt or Black Egyptian bodies.	I.	II.	III.	IV.	V.	VI.
Blue clay,.....	200	350	200	—	100	—
Red clay,.....	—	—	300	500	—	—
Ochre calcined,.....	200	300	100	75	100	—
Iron scales—protoxide of iron,.....	—	30	—	—	35	—
Manganese,.....	60	80	100	75	40	100

Red body—terra-cotta ware.

Red marl very carefully sifted,.....	10 parts.
Common marl,.....	2 parts.

with the addition of ten per cent. of Cornish clay, the light color is required.

The revival of painting upon vases and other similar articles in the manner of the ancient Etruscans, without the glossy appearance of ordinary painting upon porcelain or earthenware—an art lost since the time of PLINY—is due to Mr. WEDGWOOD, who, after careful examination of original Etruscan vases, finding it impossible to imitate the colors by *enamels*, devised other substances, termed *encaustic* colors, producing an entirely different effect, and without any of the glossy lustre of the enamels in the firing. This discovery at once enabled successful imitations of the ancient vases to be made in all their variations of light and shade, and of equal durability with the enamels, without the defect of a varnished or glassy surface. Encaustic colors are applied with great ease and certainty, changing but little in the firing, and have no tendency to run or spread on the design. The composition for certain colors may be given as follows:—

ENCAUSTIC COLORS.

White.	Black.	Green.	Blue.
Blue clay,..... 20	Egyptian black,.... 12	White slip,..... 12	White slip,..... 25
China clay,..... 10	White slip,..... 3	Blue slip,..... 1	Blue cobalt,..... 1½
Flint,..... 10	Blue slip,..... 3	Nickel,..... 1	
Cornish stone,.... 5			

These clays, finely ground and brought to the consistency of thick slip, are painted upon the wares while in their moist state, and before firing in the biscuit oven.

It is impossible to conclude this notice of the jasper wares of JOSIAH WEDGWOOD, without quoting some remarks upon the manufacture of pottery which conclude his catalogue—dated and published in 1777—remarks peculiarly applicable to the manufactures and productions of the present day. He says:—

A competition for cheapness, and not for excellence of workmanship, is the most frequent and certain cause of the rapid decay and entire destruction of arts and manufactures.

The desire of selling much in a little time, without respect to the taste or quality of the goods, leads manufacturers and merchants to ruin the reputation of the articles which they make and deal in; and whilst those who buy for the sake of a fallacious saving, prefer mediocrity to excellence, it will be impossible for them either to improve or keep up the quality of their works.

All works of art must bear a price in proportion to the skill, the taste, the time, the expense, and the risk attending the invention and execution of them. Those

pieces that, for these reasons, bear the highest price, and which those who are not accustomed to consider the real difficulty and expense of making fine things, are apt to call dear, are, when justly estimated, the cheapest articles that can be purchased, and such are generally attended with much less profit to the artist than those that everybody calls cheap.

Beautiful forms and compositions are not to be made by chance, and they never were made, nor can be made in any kind, at a small expense.—*Wedgwood.*

Fine stoneware in general is never glazed, though at times a glaze is produced spontaneously with the firing by a process called *smearing*, the inner surface of the seggars being coated with a glaze composed of—

DRY SMEARS OR GLAZE FOR FINE WHITE STONWARE.

No. 1.

Lead,.....	6
Stone,.....	3
Salt,.....	3

No. 2.

Flint,.....	10
Bone,.....	5
Nitre,.....	3
Salt,.....	5

No. 3.

Lead,.....	4
Stone,.....	1
Salt,.....	2
Flint,.....	1

No. 4.

Glaze,.....	4
Salt,.....	1
Potassa,.....	$\frac{1}{2}$

No. 5.

Calcined bones,.....	3
Common salt,.....	1

No. 6.

Bones,.....	5
Salt,.....	3

No. 7.

Flint,.....	10
Bones,.....	5
Salt,.....	5
Nitre,.....	3

WASH SMEARS.

No. 8.

Lime at twenty-four ounces,.....	3 quarts.
Slip at twenty-four ounces,.....	2 quarts.
Salt,.....	2 pounds.
Nitre,.....	1 pound.

The ingredients dissolved in hot water, and the seggars washed inside with the mixture.

This in part becoming volatilized during the firing, a portion of the alkali and oxide of lead is absorbed by the surface of the ware, forming a thin layer of glaze, both the surfaces containing silica appropriating a fair proportion of the vitrifiable bases. Sometimes a glaze containing a large quantity of lead or borax, is applied by the process described under *Porcelain* to either both or only one surface of the ware. When pigments are mixed with the glaze, colors—as is the case with yellow—are communicated to the ware which could not otherwise be produced. The firing of this kind of ware takes place in seggars, in furnaces of similar

description as those described under *Earthenware*, and often at the same time as wares of that description, being placed in those portions of the kiln where the temperature is highest.

Varnished and Larva Ware.—Other kinds of wares manufactured in Germany at Pirna and Saargemündt, and recently brought into extensive circulation for ornamental purposes, may be classed under fine stonewares, and possess a mass exhibiting a striking resemblance to porphyry or jasper, and capable of receiving the most delicate and refined forms in manipulation. The ware manufactured by UTZSCHNEIDER at Saargemündt exhibits several peculiarities—the contraction in the firing amounting to twenty per cent., while the mass is composed of three local varieties of clay, partly ferruginous, and quartz. The body, which is not glazed, but ground after firing with emery and polished with tripoly, requires the same precautions in the manufacture as that described under *Fine Stoneware*. The ware manufactured at Pirna on the Elbe has likewise a colored body, the chrome green and black masses being without glaze and dull; while the ochre-yellow mass of other varieties is often concealed by a coating of very brilliant varnish color, very different to potters' pigments, from its soft nature, fatty lustre, and easy destructibility in the fire, being, in fact, an oil paint. This varnish is laid on very smoothly and with great care, to preserve the outlines of the ornaments in relief, and afterwards when dry covered with a thin coating of copal varnish. It is secure from injury by hot water, but neither withstands abrasion by the knife, or use over the fire. Fine stoneware, as a general rule, does not stand well against heat or sudden changes of temperature.

The relative values of plastic clay for the manufacture of *fine* and *common* stoneware, with and without glaze may be here given—

STONEWARE GLAZED.

Place,	Silica,	Alumina,	Oxide of Iron,	Lime,	Magnesia,	Alkali,	Loss,	Parts,	Description,
St. Amand,....	75.00	22.10	1.00	0.25	traces	0.84	0.81	100.00	Common body, earthy glaze.
Helsingborg, ...	74.60	19.00	4.25	0.62	traces	1.30	0.23	100.00	Coarse greyish body, ill moulded, glazed with salt.
Voisinlieu,	74.30	19.50	3.90	0.50	0.80	0.50	0.50	100.00	Fine whitish body, well moulded, salt glaze.
Vauxhall,	74.00	27.04	2.00	0.60	0.17	1.06	0.13	100.00	Fine whitish body, well moulded, with a porous external surface, salt glazed.
Freechen,	64.01	24.50	8.50	0.56	0.92	1.42	0.09	100.00	Dark brown body, fine, well moulded, covered with an earthy glaze.

STONEWARE UNGLAZED.

Place,	Silica,	Alumina,	Oxide of Iron,	Lime,	Magnesia,	Alkali,	Loss,	Parts,	Description,
Baltimore,	67.40	29.00	2.00	0.60	—	0.60	0.40	100.00	Very fine whitish body.
Wedgwood, ...	66.49	26.00	6.12	1.04	0.15	0.20	—	100.00	Very fine yellowish body, very sonorous, well moulded.
Saveignies,	65.80	27.64	4.25	1.12	0.64	0.24	0.31	100.00	Clear brown body, coarse, very sonorous.
Japan,	62.04	20.30	15.58	1.08	traces	traces	1.00	100.00	Very fine body, well moulded, of a deep brown-red color.
China,	62.00	22.00	14.00	0.50	traces	1.00	0.50	100.00	Very fine body, well moulded, of a deep brown-red color.

From which tables it appears that stonewares may be divided into two classes—those containing from seventy-five per cent. of silicic acid, and others of from sixty-two to sixty-six per cent. Experiment further proves that an excess of silica in the body is very favorable to the production of a good glaze.

Ordinary Stoneware—one of the characteristics of which, namely, the semi-fused state of the mass, results from the much stronger heat of the kiln, and not from the addition of flux. The composition is more simple; only one addition being made to the plastic clay, which, having no tendency to shrink in the furnace, prevents the clay from any very serious contraction, the amount of which varies, as in the finer stonewares, from eight to ten per cent.

As the plastic clays generally possess this property of contraction in a high degree, objects formed from them without this addition and tolerably thick in the sides, infallibly crack in the firing.

The action of such additions has been determined experimentally upon the plastic clay of Dreux mixed with—

	Contracts,
10 per cent. ground fragments of stoneware,	15 per cent.
25 " " " "	5 "
10 " " whole sand from Aumont,.....	18 "
25 " " " "	15 "
50 " " " "	9 "
10 " " " "	17 "
25 " " " "	15 "
50 " " " "	12 "
No addition, clay in natural state,	10 to 11 "
No addition, clay purified by suspension in water,.....	17 "

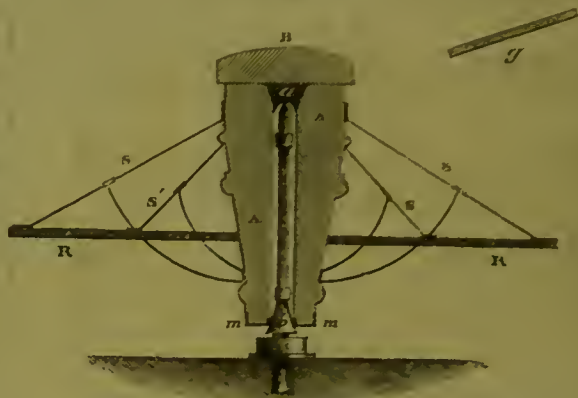
From which it appears that the plastic clay under experiment contained in its natural state an admixture of some substance that diminished its power of contraction, and which was removed from it by decantation in water, increasing the contractile power. In the potteries a very important practice is adopted, that of combining together the several kinds of clay found to produce the best result in the fire, both as regards the contraction, color, and refractory nature of the mass.

In the manufacture of ordinary stoneware vessels, such as jars for preserves or pickles, milk pans, *et cetera*, the process of decanting the clay from water would be too costly, and the coarser impurities which might interfere with the formation of the ware, are therefore either removed by repeated kneadings and treading out of the mass by manual labor, or separated by passing the clay through the *pug mill*—see *Earthenware*.

The low price at which these wares are purchased in the market necessitates the adoption of the most simple modes of forming and manipulation; they are generally, therefore, thrown upon the potter's wheel, already described under *Porcelain*. From the large dimensions of the vessels that sometimes require to be formed, increased facilities are given to the workman for producing greater persistence in the rotatory motion of the wheel, and using larger plates or discs for the support of the mass. These arrangements are shown in Fig. 484p. The cast-iron wheel, *rr*, is connected to

the hollow shaft, *AA*, carrying the head or disc of the lathe by double spokes, *ss'*, *ss'*. The top of the hollow shaft at *a* is fitted with an iron cup, into which the top bearing of the supporting axle running through the centre works, while the lower extremity of the hollow

Fig. 484p.



shafts, *mm*, being of iron, rests upon the conical support, *b*, of the axle. The wheel and shaft, therefore, turn with little friction, being suspended after the manner of a ship's compass. For the greater convenience of the workman, who sits at the bench, *g*, the surface of the disc, *B*, is placed below his level. Impulse is given to the iron wheel by a pointed rod, the rotatory motion lasting long enough for one operation, and the high degree of plasticity in the mass being of great assistance. The help of an assistant to turn the wheel is therefore only required when a great amount of resistance has to be overcome. Vessels of a wide bulging shape and of moderate dimensions are first thrown in the form of a hollow cylinder of the intended height and width, the contraction being afterwards effected by pressure against the mass in its revolution; larger vessels of similar form are put together from two halves separately formed, the handles, *et cetera*, which are made by hand, being simply pressed on to the mass. In the firing of common stoneware, horizontal kilns or furnaces are used, in which the draught has a direction more or less parallel with the floor. It is only in kilns of this construction that the wares can be placed alongside of each other, instead of being piled up in columns or bungs. By such an arrangement of draught, however, the heat of the furnace is very irregularly distributed. All common stoneware in the firing is exposed directly to the action of the flame, the nature of the surface not rendering the protection from dust and scratches by the use of seggars necessary.

The kiln—Fig. 484q—is in general roughly constructed, the grate, *r*, separating the ashpit, *c*, from the hearth, *b*. The portion of the kiln where the wares are fired is shown at *A*, an elliptical arched dome, *aa*, covering the whole. The draught is regulated by a plate covering the aperture, *g*, the fire being supplied with fuel through *c*. By this arrangement the flames carried by the draught pass through the apertures, *ii*, in the wall, *mm*, to the chamber containing the wares, from which they enter the chimney, *o*, by the holes, *nn*. The wares are introduced into the kiln by doors which

are bricked up during the firing. At Lambeth, near London, the kilns assume a vertical character, are about ten feet in diameter in the baking chamber, and

in square cells formed by placing stout tiles upright in rows, with others laid horizontally upon the top—the heavier and coarser portions of the ware

being placed upon the top. These cells or boxes generally occupy one-half the height of the kiln. Great care and experience is required in the management of the fires, as, if too little air is admitted, the smoke and gas will be imperfectly consumed, and the wares discolored; while, on the contrary, if air enters too freely the heat is not sufficiently intense to vitrify the clay. The heat of the furnace often attains 120° Wedgwood, this ware requiring the most intense heat, after real porcelain, of any kind of pottery.

Common stoneware, being sufficiently dense and vitreous in its mass to be impermeable, requires no glaze, but by a very cheap and

simple process the dull surface is made smooth and lustrous. A natural glaze, or the waste from other branches of the manufacture, is used, ground to a fine powder, and sifted or sprinkled over the moist ware in a thin stratum; it is afterwards burnt on in the process of firing. Iron slag is generally used for this purpose, the large proportion of the oxides of iron and manganese which it contains rendering it of easy fusion.

Salt-glaze.—The simple and old-fashioned salt-glaze is also of very general application. Its discovery, dating about the year 1680, is said to have been accidental, the tradition being that at Stanley farm at Baguall, about five miles East of Burslem, the servant of Mr. JOSEPH YATES was boiling a strong brine of salt, to be used for curing pork; during her temporary absence the liquor boiled over the sides of the earthen vessel used for this purpose, and, becoming very hot, the vessel on cooling had a glazed surface. A Mr. PALMER, who carried on a small pottery about a mile from the farm, availed himself of the hint, and commenced a manufacture of ware glazed with chloride of sodium, which was readily procured from the salt wyes—Middlewich and Northwich in Cheshire. The process of glazing with salt takes place towards the end of the firing, when salt is thrown into the kiln through particular apertures. The temperature of the kiln being considerably above a red heat, volatilizes the chloride into a vapor which, filling the chamber, surrounds the wares, and causes a reaction to take place with the silica of the mass. These two substances, silica and common salt, only act upon each other in the presence of aqueous vapor, and which is always present in the flame of the furnace. With the sodium of the chloride, the oxygen of the water produces soda, which enters into combination with the silicic, while the hydrogen unites with the chlorine, and is evolved as hydrochloric acid— $\text{NaCl} + \text{H}_2\text{O} = \text{NaO} + \text{HCl}$. The glaze is, therefore, a soda glass, and exists as a very thin coating upon the surface of the wares. Clays which contain less than fifty per cent. silica are without action, and do not decompose salt. A brown color is

Fig. 484q.

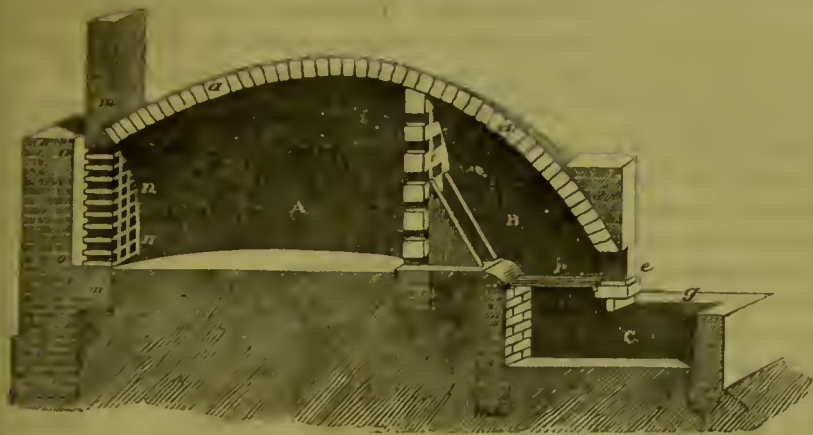
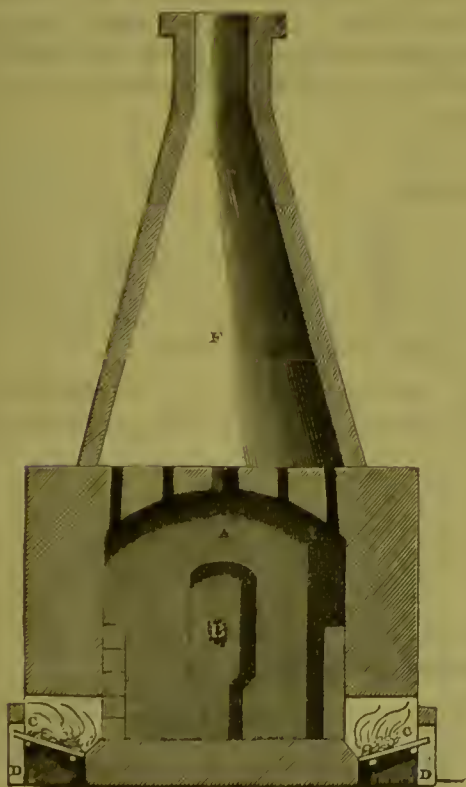


Fig. 484a.



kilns: A is the baking chamber; C the fire-grate; D the ash-pit; and F the bag or chimney, the wares being introduced by the opening, B, bricked up during firing. In the kilns used for common stoneware, the smaller articles are placed at the bottom part of the kiln,

the larger at the top.

communicated to the wares by throwing into the furnace, during the glazing process, substances which afford a large volume of smoke, such as the bark of the birch tree.

Common stoneware generally varies in color from grey to bluish-grey, yellowish-red, brownish-red, and brown.

The manufacture of stoneware by *moulding*, has recently been brought to great perfection, and most of the vessels used in chemical laboratories are formed in this manner, the smaller articles being remarkably thin and light. The larger vessels for chemical works, such as acid bottles, *et cetera*, are sometimes of enormous dimensions, and constructed to contain from one hundred to three hundred gallons. The agreeable brown color of these vessels is produced by dipping them into water containing oxide of iron in suspension.

The principal seats of the manufacture of common salt-glazed stoneware are at Glasgow, Lambeth, Belper, and Nottingham; the other variety of common glazed stoneware being produced at Bristol and Chesterfield, while the fine stoneware manufacture is almost exclusively confined to the neighborhood of the Staffordshire potteries. On the Continent the manufacture is extensively carried on at several places, particularly at Buntzlau in Silesia, and at Vallendar, on the Rhine opposite Coblenz, where two kinds of clay are worked—a blue clay for grey ware, and a yellow clay for red ware. At Buntzlau the wares are colored brown by immersion into a solution of marly clay after the manner of a glaze.

EARTHENWARE.—Under the term *earthenware* are embraced many varieties of pottery, which in fracture have all an earthy appearance, are perfectly opaque, and are coated with a soft, easily fusible glaze,

containing lead or borax. But, notwithstanding they all possess these characteristics, the modifications and varieties of this ware are more numerous than those of any other kind. The several kinds of clay—plastic or pipe-clay, potters' clay, and marl, to which quartz is sometimes added—enter into the composition of all earthenware. The absence of any real flux, and the circumstance of its being fired at a temperature which precludes the partial or entire fusion of any one of its constituents, distinguishes earthenware from porcelain and stoneware, while the greater care bestowed upon the preparation of the materials, and consequent greater purity of the mass, together with the general absence of color, are sufficient to mark the distinction between this and delftware.

Fine Earthenware.—The English manufacture may be selected as the type of this ware; it is composed essentially of a mixture of plastic clay and quartz, and is, therefore, more refractory, harder, and denser than the delftware, the chief ingredients of which are potters' clay and marl, and which is in consequence soft and calcareous. Fine earthenware again is always coated with a transparent glaze; the commoner sorts with enamel, producing the favorite *Majolica* ware. Neither kinds, however, are fitted for culinary use, as they either split when exposed to heat, or the glaze becomes cracked and crazed.

The crude materials used in England in the manufacture of fine earthenware, are Cornish stone and China clay, a kind of kaolin brought from Cornwall, and varieties of plastic clay, both of which burn white, and chalk-flints. That class called *ironstone china* is made from a mixture of plastic clay, kaolin, Cornish stone in excess, and silica, the formula of which is as follows:—

IRONSTONE CHINA BODIES.

	I.	II.	III.	IV.	V.	VI.
Cornish stone	180	200	700	600	600	400
China clay	120	150	500	600	100	250
Blue clay	60	100	300	—	180	150
Flint	80	120	250	400	60	75

A small proportion of cobalt blue is added as a stain to whiten the mass.

These are the three principal modifications into which this class of claywares may be subdivided, leaving innumerable others of an intermediate character. Mixtures for the mass of the following varieties are given below:—

FRENCH.

Plastic clay from Montereau and Dreux	87
Quartz	13

ENGLISH.

CREAM COLORED WARE BODIES.

Slip mixtures by measure; *Dry* mixtures in parts.

	Dry mixtures.		Slip mixtures in inches.		
Blue clay	22	12	11	13	12
China clay	9	12	6	3½	4
Flint	5½	10	4	2½	3
Cornish stone	—	—	3½	4	—

Turquoise Body.

Blue clay	300 lbs.
China clay	175 lbs.
Flint	200 lbs.
Cornish stone	60 lbs.
Turquoise stain	20 lbs.

Turquoise stain consists as follows:—

Blue cobalt	1 lbs.
Flint	2½ lbs.
Oxide of zinc	10 lbs.

Calcined together in earthenware biscuit oven, and finely ground for use.

Pale Drab Body.

Fine white earthenware body	700 lbs.
Stain—nickel	4 lbs.
Cobalt calx	1½ lbs.

Ruff Body.

Finely ground grey marl	100 lbs.
Fine earthenware body	100 lbs.

Inside Wash for above colored bodies.

China clay	40 lbs.
Blue clay	20 lbs.
Flint	20 lbs.
Cornish stone	10 lbs.
Cobalt calx, to whiten	15 drachms.

This wash is poured smartly into the interior of the ware after forming, and immediately emptied.

COLORED CLAYS FOR ORNAMENTATION.

Turquoise or blue, take of the body of the ware 40 lbs., and 1½ lb. of the turquoise stain.

Green Clay.

Body	40 lbs.
Nickel	3 lbs.
Cobalt calx	¾ ounce.

Drab Clay.

Body	60 lbs.
Nickel	12 ounces.
Cobalt calx	3 ounces.

Dark Chrome Green Clay.

Body	40 lbs.
Oxide of chrome	3 lbs.

Orange Clay.

Body	40 lbs.
Fine red marl	20 lbs.
Flint	7 lbs.

In general use for moulding and pressing.

FINE EARTHENWARE BODIES.

In *Slip* by measure.

Slip mixtures in inches in tub.

	Ounces to the pint.	I. Inches.	II. Inches.	III. Inches.	IV. Inches.
Blue clay	24	7½	12½	7	9
China clay	26	9	5	9	7
Flint	32	3	3	5½	5
Cornish stone	31½	½	—	2½	3

Dry in parts.

	I.	II.	III.
Blue clay	200	500	500
China clay	200	800	650
Flint	200	800	450
Cornish stone	75	300	200

TERRA-COTTA, OR POROUS BODIES FOR WATER BOTTLES, ETC.

	Green.	Blue.		Red.
Earthenware body	100	100	Dark red marl	300
Cornish stone	15	10	Blue ball clay	100
Oxide of chrome	3	3	Turquoise stain.	

	Can.	
Grey marl	120	The marls should be very carefully sifted through fine lawus, and if ground finely in a pan at the mill, the body will be much improved. This remark applies to all colored bodies.
Blue clay	13	
Flint	6	

These porous bodies are all fired in the glazing oven.

Preparation of the Material for forming the Mass.—

The flints are prepared for the grinding process by crushing in their calcined state under the stamping-mill—Fig. 484s—which consists of a series of upright beams, *a, a, a*, of wood, shod at their lower extremities with heavy iron shields, *b, b*. These beams being alternately raised in a vertical direction by means of projecting pins, *c, c*, catching the arms of a revolving drum, *d*, fall with great force into a long narrow trough, *f*, placed in a horizontal direction underneath, and having its bottom formed of perforated cast-iron plates, *m*, through the holes of which the broken calcined flints pass, and are then ready to be conveyed to the block-mill.

The mill room where this grinding process takes place is fitted with a number of circular vats—Fig. 484t—from ten to twelve feet diameter; the bottoms of which are paved with square blocks of a very hard stone. These vats are fitted with arms in the same

manner as the mixing vats described under *Poreelain*. Blocks of stone weighing from ten to fifteen hundred-weight are placed against the arms, which are driven round by machinery. Into these vats the broken calcined flints are thrown, and water is introduced to prevent the escape of the finer particles of dust, which would be very injurious to the workmen. By this process the flints quickly acquire a state of minute division. After a period of about twelve hours the contents are run off through troughs into washing tubs or vats, where the coarse or heavier particles subside, the fine liquid flint passing into spacious reservoirs built and paved with bricks, and which are furnished with plugs, to enable the workmen to draw off the first water with which the grinding process took place, and bring the flint into a state fit for use.

The *Cornish stone* is brought from Cornwall in masses for the purpose of being ground and prepared, but without the process of calcination, and is used in

the bodies, besides being a most valuable ingredient in the composition of the glazes.

The process of grinding *glazes* is similar to that of

flint grinding, but the vats or pans employed are generally of smaller dimensions. The requisite machinery not being erected at all the manufactories, the potters are usually supplied with the materials prepared ready for use, by mills established in the localities where this process is carried on.

A species of stone, which has been termed *Lagnatia quartzite*, and is found in Scotland upon the estate of

Ardsheal, Argyllshire, has been recently introduced by Mr. MILES LOCKHART into the Staffordshire potteries for the purpose of grinding the flint. Being composed almost entirely of pure silica, it is harder and more durable than the material formerly employed, which, from the purity of its substance, and the entire absence of any injurious ingredient, the flint slip is left pure and free from admixture caused by the abrasion of the mill-stones. When by friction the *papers* or *runners* have become too light, they are coated with the flint, and afterwards ground up with them.

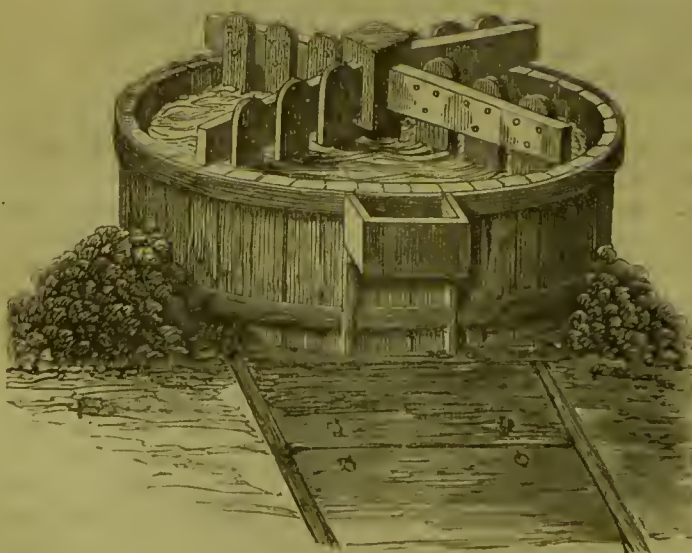
To increase its plasticity, the China or Cornish clay is mixed with much blue clay as the quality of the ware admits. Where machinery is employed the lumps of clay are thrown into the blending vat, and stirred up with water, as a ready described under *Porcelain*. The liquid with the clay in suspension is then decanted, and passes into vats in the *mixing* or *slip house*—Fig. 484t. The clays are brought up by a lift to the floor of the room where they are macerated by water, and pass into the tubs, *a* and *b*. The China clay, *a*, is brought to the standard of twenty-six ounces to the imperial pint, and that at *b*, containing the Dorsetshire or blue ball clay, to the standard of twenty-four ounces; the ground flint contained in the trough at *c* is likewise brought to the standard of from thirty-one and a half to thirty-two ounces, while the Cornish stone at *d* is of the standard weight of from thirty to thirty-one and a half ounces to the imperial pint. The China clay and blue ball clay having been admitted into the tanks, *e* and *f*, severally, in the proportions marked upon the gauge rods, *s s*, are united in the mixing cistern, *g*, the blue ball clay passing by the trough, *n*. The relative proportions by measure of Cornish stone and flint are now added, and mixed with the mass, which then passes into the trough, *t*, furnished with plugs and holes, *c' c' c'*, in its bottom, immediately over a set of fine silken sieves, *a' a' a'*, fixed in a frame, *p*, to which a sifting motion is imparted by attachment to the eccentric and rod, *d'*, worked by the engine. This lateral to and fro motion of the sieves cause a complete filtration of the slip into the tank, *h*, all the coarser impurities being left behind. From this tank, *h*, it is conveyed by the pump, *j*, and spout, *k*, into the trough, *c'*, where it undergoes a second and similar process of filtration through finer sieves, falling into the reservoir, *i*, and is conveyed away by the pumping apparatus, *m*, to the purifying machine, and for conversion into *slip* of the proper degree of consistency for working.

The *purification* of the slip by the abstraction of all particles of iron which have become incorporated with

Fig. 484s.



Fig. 484t.

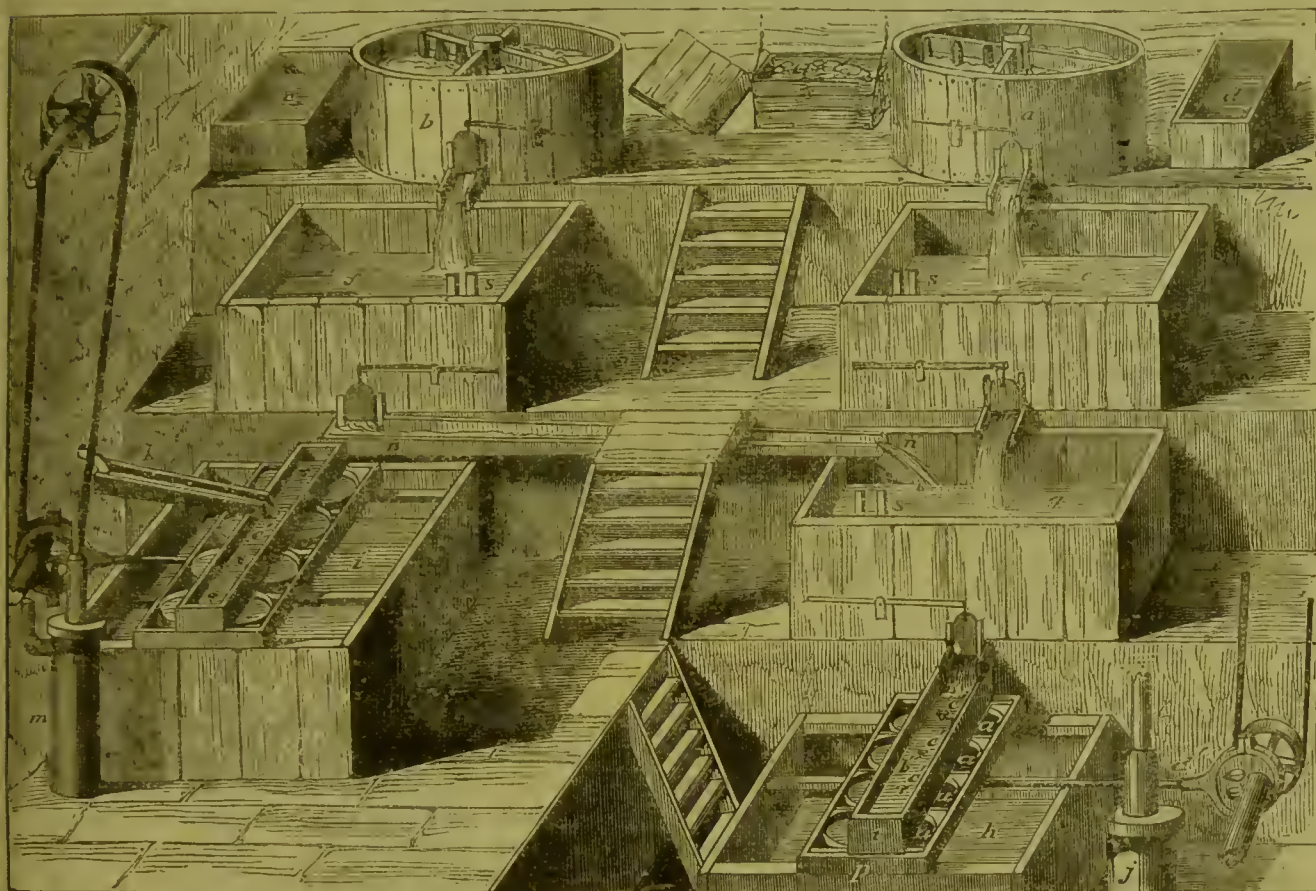


Ardsheal, Argyllshire, has been recently introduced by Mr. MILES LOCKHART into the Staffordshire potteries for the purpose of grinding the flint. Being composed almost entirely of pure silica, it is harder and more

it, from the abrasion of the iron hoops of the mill during the process of grinding, is one of great importance,

as were these impurities to pass with the mass through the process of firing, the iron, being converted into an

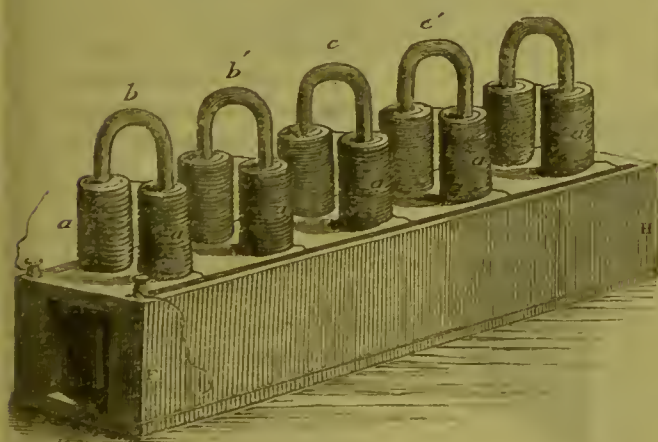
Fig. 481v.



oxide, would produce a brown or yellow stain upon the white surface of the ware. A clumsy and expensive method is frequently used to extract these par-

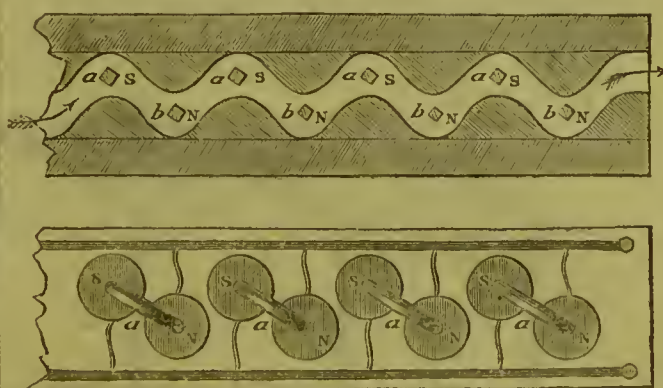
iron removed—a work of extreme labor and time, in consequence of the electricity of the magnets remaining constant. Greater simplicity, economy, and cer-

Fig. 484v.



ticles from the mass, by placing in a box a large number of small horseshoe magnets suspended upon a frame. The slip or glaze, as the case may be, is poured by an attendant into the box, and the frame containing the magnets afterwards agitated to bring the slip into contact with them; by this means the iron particles are attracted to the poles of the magnets, which are afterwards taken out one by one from the trough, and the

Fig. 481w.



tainty have been given to this operation by Messrs. HOLMES and CORDON, who have recently patented an invention which, by the application of electric currents for inducing magnetism in soft iron, effectually purifies the slip or glaze from all such particles in a much shorter time, and at a great saving of expense to the manufacturer. One form of the apparatus is shown at Fig. 484v. *a a a*, are a series of coils inclosing the electro-magnets, *b b', b b', c c', c c'*, the coils being placed in such

a manner that the induced magnetism in the alternate poles of each set shall be of an opposite nature—Fig. 484w; the arrangement of the North and South poles is shown at *a* and *b*. The slip, in its passage through the machine, comes into contact successively with the several poles of the magnets; and the particles of iron being attracted by them, the slip is thoroughly cleaned from iron by the operation. The apparatus is placed in a strong box, *E*, with two apertures, *F* and *H*, for the passage of the slip through the machine.

The slip, which is now much too liquid, passes into the slip-house for consolidation in troughs of brickwork from eighty to one hundred feet or more in length, and about four feet wide by fourteen inches in depth. The fire, placed at one end, passes by means of flues under the bottom, which is constructed of tiles, into the chimney at the further end, by which means the whole of the heat is economized. The slip, upon reaching the boiling point, throws up a dirty seum, which is scooped off, the tumultuous ebullition preventing the separation of the particles, and securing the uniform mixture of the mass. This process requires about eighteen hours, care being taken to prevent any portion of the mass from burning during the evaporation.

In extensive manufactories where machinery is used, the beautiful apparatus patented by Messrs. NEEDHAM and KITE, for consolidating the slip by pressure, is being introduced, and is a decided improvement upon the old process of evaporation by heat.

bolted together by iron clamps, *b b*, in pairs, and forming the mass, *A B*. These separate compartments are each fitted up with a series of small wooden grooves or channels, *d d d'*—Fig. 484y—sunk half an inch below the level of the frame, *a a*, and having a canal or passage, *b b*, cut top and bottom of the passage of the

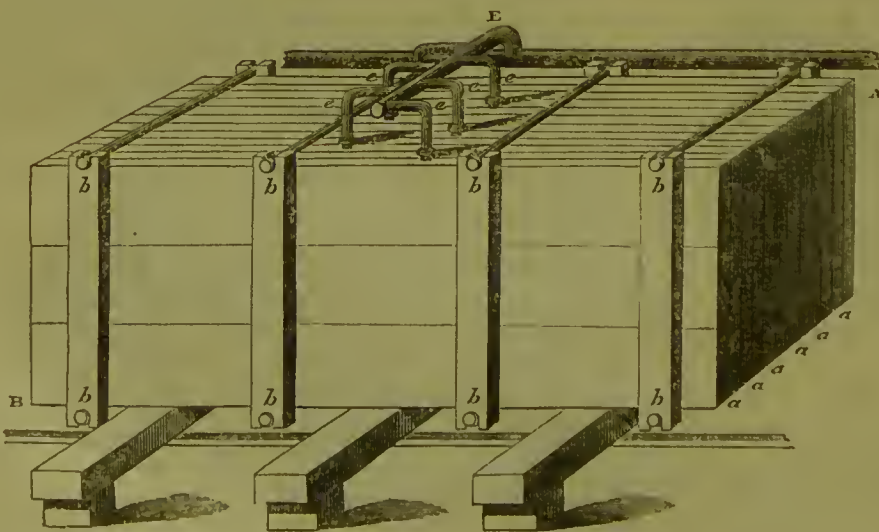
Fig. 484v.



water pressed from the slip through the holes, *c c*. By this arrangement each pair of frames when placed together will have a space between the grooves of one inch, into which the slip is forced by means of the connecting pipes and apparatus, *E*, each pair of frames having its separate supply pipe, *e*. The interior of the chamber is prepared for the reception of the slip by the insertion of a strip of fine hempen cloth, *f f*, the edges being wrapped and folded up to form a large bag, and the nozzle, *n*, for receiving the supply pipe, *e*, being permanently fixed on the double fold of the cloth. The weight of the bag is supported by the

hooks, *g g*, upon the upper portion of the frame. The machine being screwed up tightly by the rods, *b b*, the pressure is brought on by the pumps, and the water passes out through the fibres of the cloth and grooved channels, leaving the slip in the form of a thin, solid, compact, and plastic sheet of clay. The time required for the operation varies from an hour to two hours and a half according to the composition of the mass, the charging and discharging of the machine occupying an hour. Each machine can produce at the rate of four tons of prepared clay in the day. In order to strengthen the fibres of the

Fig. 484x.



The machine—Fig. 484x—constructed of stout wood, in the form of a rectangular mass, is composed of a series of separate chambers or compartments, *a a a*,

stand better the pressure and abrasion of the grooved surfaces of the chambers, it is dipped into a solution containing half an ounce of alum to a gallon of water,

an operation found greatly to increase its durability and resistance to wear and tear. Some statements of the expense and performance of these machines, compared with the old process of evaporation, are given below:—

COMPARATIVE COST OF CONSOLIDATING THE CLAY FROM THE SLIP.

By the Old Evaporating Kilns, over a period of six months.			By Needham and Kite's patented process, over a period of six months.		
1000 tons clay at 1s. 4d.,	£66	13 4	1000 tons clay at 3s. 6d.,	£175	0 0
Wear and tear of kilns,	32	0 0	Milling, at 4d.,	16	13 4
750 tons coal at 4s. 9d.,	178	2 6	Steam-power,	20	0 0
			Patent right per ton 6d.,	25	0 0
				£236	13 4
			Saving,.....	40	2 6
				£276	15 10

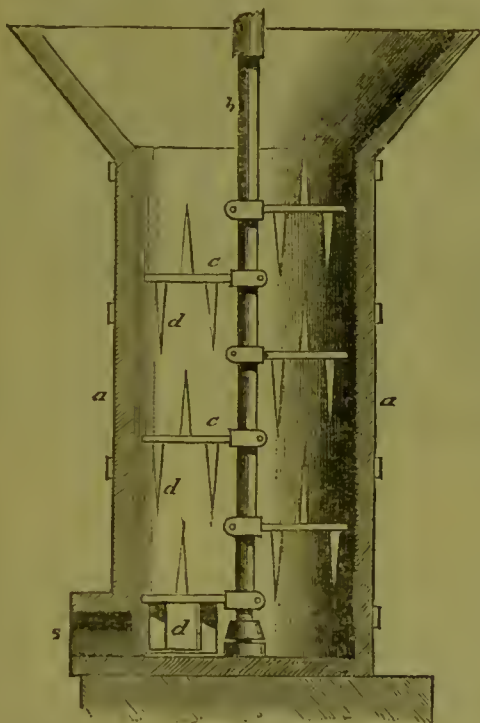
£276 15 10

£276 15 10

The cost of preparing the slip is in each case 8d. per ton.

The slip in this state passes through the *clay* or *pug-mill*—Fig. 484z—in order to bring the mass to a

Fig. 484z.

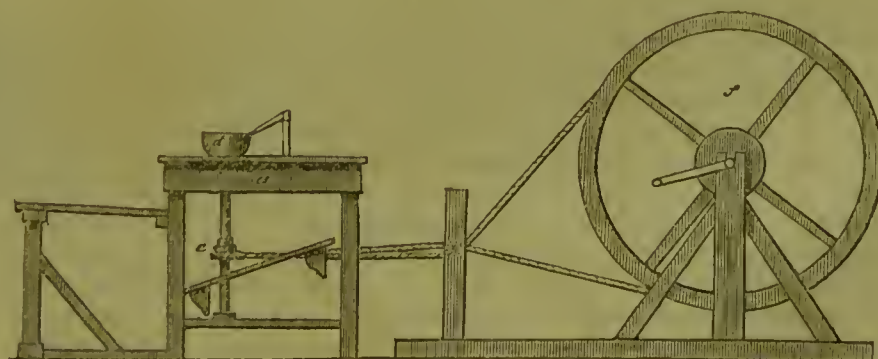


uniform consistency. The mill consists of a circular iron vat or cylinder, *a*, bound together by iron hoops, through the centre of which the iron shaft, *b*, revolves, carrying with it several horizontal arms, *c*, armed with the sharp blades, *d*; these are fixed in a horizontal position, and inclined at a certain angle; by this arrangement the clay in its passage through the mill is cut up and forced out at the aperture, *s*, the mass constantly sinking as it is supplied with fresh clay from above, and separated as it issues from the machine, by means of a fine wire, into blocks, which are carried away to the store house for the process of *ageing*—see *Porcelain*. Before the mass is placed in the *thrower's* hands it under-

goes a further state of preparation, termed *slapping* or *wedging*, by being forcibly thrown upon a strong slab of plaster of Paris. The workman then divides the mass, and the piece cut off is again brought down with considerable force upon the other portion, a continual dividing and slapping of the mass being continued until the whole is of a perfectly homogeneous texture; at the same time care is taken not to cross the mass, but to *slap* the pieces together in the relative position from which they were cut, as, if this precaution were not observed, the ware would afterwards contract unequally in the firing. From twenty to twenty-five blows are given to the mass before it is sufficiently homogeneous for manufacture.

Throwing.—From the much greater plasticity of the mass used for earthenware, the operation of throwing upon the wheel is one of greater rapidity than is the case with the manufacture of either porcelain or stoneware, an experienced *thrower*, assisted by two boys, often producing as many as from twelve hundred to fifteen hundred eight-inch basins in a working day of ten hours; while between two thousand and three thousand of the small round ink bottles may be produced in the same time by a lad and his assistant. This extreme facility in the manipulation is certainly one of the principal reasons for the low price of the ware. The potter's lathe, in its general form, where machinery is not employed, is shown at Fig. 484AA, and consists of a fixed table, *a*, carrying an upright shaft, *b*, to which the *throwing* disc or head, *d*, is fixed for receiving the

Fig. 484AA.



mass of clay. *e* is a pulley fixed on to the shaft with grooves of different diameters, and receives motion from the driving wheel, *f*, by a cord passing under the

guide pulley upon the frame, *g*. The workman, seated upon the bench, *h*, regulates the velocity of his disc in the shaping of the mass by corresponding signals to the assistant who turns the wheel, *f*.

In the manufactories of WEDGWOOD and COPELAND, the lathes are driven by engine power, the arrangement

for regulating the speed, *et cetera*, being shown at Fig. 484BB. *a* and *b* are two conical drums, connected together by the belt, *c*, and to which motion is communicated by the driving wheel, *d*. The thrower sits at his table, and the axle, *e*, carries the disc, on which are placed two pulleys, *m, n*, one fixed, the other loose

Fig. 484BB.



in connection with the drum, *b*, by means of the strap, *f*. The revolution of the lathe is thrown off and on by the treadle, *h*, under command of the operator's foot. The speed of the lathe is regulated by the assistant, who elevates or depresses the belt, *c*, upon the drum, *b*, by means of the winch and carrier, *s*, through which the strap works.

The *baller*, who prepares the mass for the *thrower*, is shown at *D*. Each piece is weighed when the vessels require to be of a uniform size, a stroke or two of the hand being given before it is pressed into the balls, *r*, ready for use by the thrower, who, after the formation of the vessel, dexterously separates it at the base from the disc by a fine brass wire, and places it on a board, where it remains until the mass becomes sufficiently firm to bear without injury the subsequent processes of turning, handling, *et cetera*.

Turning.—This manipulation requires considerable dexterity on the part of the workman, to avoid destroying or fracturing the piece whilst turning it to the requisite size, thickness, and shape, and presents also numerous opportunities for the exercise of skill, taste, and genius in giving to the several parts the prominence required, and to the whole the degree of elegance suggested by the pattern.

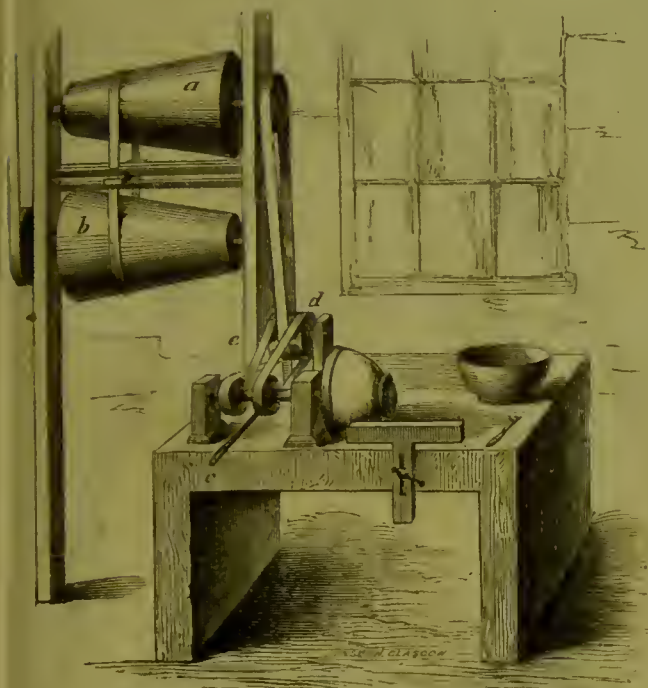
The common horizontal lathe resembles that in use for wood turning, and is generally set in motion by

male or female assistants, who by practice become remarkably apt in adapting the velocity of the motion to the requisitions of the turner, and at the same time perform all the necessary attendant operations, such as stamping the goods, and bringing them to or from the lathe. The vessels are fixed upon the headstock of the lathe by insertion upon a chuck of a tapering form, which easily adapts itself to the inner surface of the vessel. The engine-lathe, turned by steam power—Fig. 484CC—has the speed regulated by the gauge, *b*, shifting the position of the band upon the driving drum, *a*. The motion of the lathe is reversible by the lever, *c*, changing the position of the driving belt from the direct motion pulley, *d*, to that of the reversed one, *e*. This retrograde motion is required for the final operation of smoothing, solidifying, and polishing the vessel after turning.

The turner's tools are of iron, thin, and well forged, about eight inches in length, and varying in breadth from a quarter of an inch to two inches, the cutting end being turned up at a right angle about half an inch, and made sharp and level upon the grindstone. All wares that are not circular in section, and such as are ornamented with bas-reliefs, are made in plaster moulds, into which the mass is pressed with a sponge, *et cetera*. Thin vessels are made at the wheel, with the assistance of plaster moulds and tools, as already

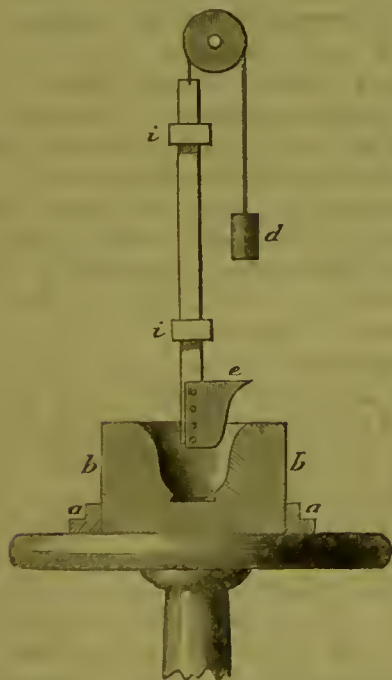
described. When simple forms are required in great quantities, the hand of the moulder has lately been replaced by machinery, more particularly in some of the Northern potteries about Glasgow, Newcastle-upon-

Fig. 484cc.



Tyne, and Yorkshire. Fig. 484DD represents a form of the apparatus in which the cups are formed by means of the plaster mould, *b*, giving the exterior form, while

Fig. 484DD.

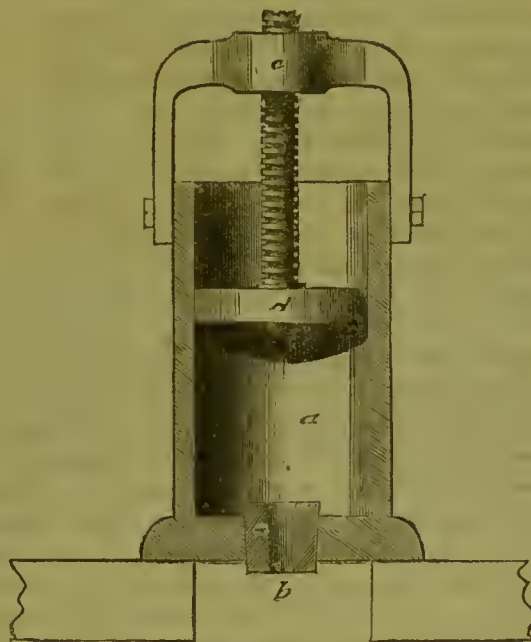


the tool, *e*, gives the interior shape. The plaster mould is fixed in its proper position upon the head of the disc by the iron ring, *a a*, in such a manner that its centre corresponds exactly with the point of the tool. The mould is brought into revolution by means of a treadle, while the tool, *e*, counterpoised by the

weight, *d*, is lowered to the proper distance through the guides, *i i*, by means of a second treadle. When a ball of clay is placed in the mould, and the treadles moved, the tool, *e*, descends into the revolving mass of clay and bores a hole, forming a cup, the thickness of the sides of which will correspond to the distance at which the tool, at its lowest point, is separated from the sides of the mould. When the forming is finished, for which a few seconds suffice, the treadles are set at liberty, and the mould brought to a state of rest; the tool being raised up above the mould by the weight of the counterpoise, *d*. The mould, with the finished piece, is then exchanged for another, and the operation repeated. A machine of this kind can be worked by female labor at a less cost than that of experienced moulders.

Handling, et cetera.—These manipulations are performed, for the better class of wares, by moulding in the same manner as that described under *Porcelain*, while for handles of a less ornamental nature, recourse is had to a small machine, called the *squeezing box*. This consists of an iron cylinder, *a*—Fig. 484EE—about six inches in diameter, and twelve inches deep, the

Fig. 484EE.



bottom of which has a hole, into which a piece of lead, *b*, is inserted, pierced of the size and section of the intended handle. The upper edge of the cylinder carries a strong iron frame, *c*, into which works a screw plunger, *d*; this, upon depression, forces the clay through the aperture in stripes of the proper form, and which afterwards, when cut into lengths and bent as required, are left to acquire their proper consistency before application to the wares. In this operation the handler cuts away from the edges or ends all superfluous clay, and, after moistening with slip the parts of contact, presses them gently against the body of the ware; they are afterwards trimmed with the knife to remove all superfluous matter. The vessel is then rubbed over with a moist sponge to remove all dust, previous to drying and placing in the seggars for the baking process.

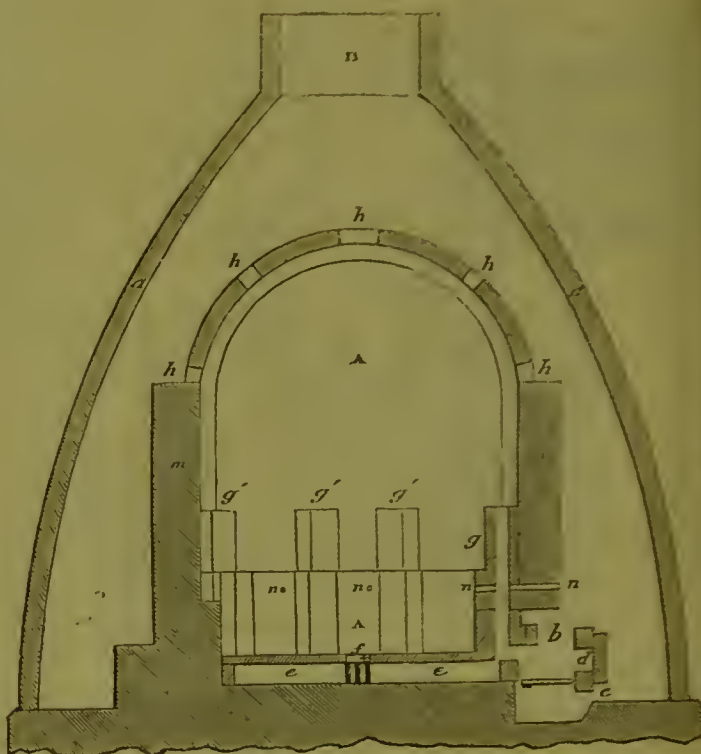
Pressing, or hollow-ware squeezing, is a more laborious manipulation connected with this branch of manufacture.

The clay having been prepared by beating with the bat upon the gypsum slab to the proper thickness and dimension, is placed upon one of the sections of the mould, and with a moist sponge well worked into every part. All the sections being thus lined with clay, the edges are trimmed, and the parts of the mould carefully placed together, and secured in their position by a strap passed round them. The presser then passes his finger up every joint, so as to make a groove, into which a thin roll of clay is inserted, and worked into the mass by the finger, and smoothed with moist leather. All marks are removed with a sponge moistened with slip, and the inside is afterwards washed with clean water and a sponge. The mould and its contents are then set aside until firm enough to receive polish with a flexible horn plate. The article is afterwards removed from the mould, trimmed and polished with proper tools, to remove all appearance of seams, and the handle, spout, or other ornamentation, added in the usual way before baking. One mode of decoration which may be here described consists in the formation upon the ware, while in the lathe, of rings and devices in various colors. This decoration is produced in different ways. When an inlaid pattern in various hues, the workman, while the ware is in the plastic state, and revolving upon the headstock of the lathe, impresses the pattern upon the surface by a roulette, and afterwards blows through a fine tube, out of a bottle, thick colored slips into the several sunk parts, the bottles containing the slip being furnished with a mouth-piece and tube for that purpose. The surplus colored clays being afterwards turned off in the manner described under *Fine Stoneware*, the various inlaid rings of color are produced. When a marbled appearance is required, the tinted mixtures are placed in separate compartments of one vessel furnished with a spout in connection with the several chambers. On their exit from the vessel, all the colors flow out in a single stream, but unmixed with each other. This stream flowing upon the ware causes a waved or variegated appearance according to the regularity of the motion given to the piece, and articles so decorated, are commonly termed *depped* and *mocha* ware. All these colored clays require to be in the *slip* state, and not of an oily nature. The wares are afterwards fired and glazed as usual, according as the nature of the operation has been performed while in the plastic or biscuit state. A pleasing arborescent effect is sometimes given to these wares by a mixture of tobacco water, with manganese, nickel, oxide of iron, and a small quantity of cobalt, dropped on to the soft colored slip surface of the ornamentation.

Firing.—The temperature at which fine earthenware is baked being much higher than that required for the glaze, renders it necessary that vessels composed of this substance should be fired twice. At the first firing

the ware is completely baked, or converted into brick, the glaze only being burnt on in the second firing. Two separate furnaces are employed for these distinct operations. The kiln used for baking—Fig. 484rr—has only one chamber, A, and is surrounded by

Fig. 484rr.



conical brick building, *a a*, termed a *hovel*, that serves at once the purpose of roof and chimney. The construction is nearly the same as that of an upright reverberatory furnace, differing from the porcelain kiln by a better arrangement for the distribution of the flame, and the use of coal for firing in place of wood. The draught is regulated by the aperture, *b*, and passes into the furnace in a downward course, carrying with it the flames in a horizontal direction; *c* is the opening for removing the cluders, and *d* that by which fuel is introduced into the furnace. The flame, before entering the chamber of the furnace, is divided; part of it retaining its original direction, passes through channels below the sole of the furnace, along the horizontal flues, *e*, and enters at the central point, *f*, the remainder circulating upwards through the small chimneys or bags, *g*, situated against the wall, *m*, of the kiln, *A*. Each fire, of which there are six or eight, has a corresponding chimney, *g' g'*, and horizontal flues converging towards *f*, and becoming narrower as they approach the centre. The flame finally escapes through the openings, *h h h*, in the dome of the chamber, *A*, and out of the top of the hovel, *B*. The small openings, *n n*, are for the removal of the *watches* from the seggars placed opposite, and by which the potter ascertains the state of the kiln. The height of the chamber, *A*, averages about eighteen feet, the diameter about sixteen feet.

It being generally the custom, in the manufacture of fine earthenware, to prepare several kinds of goods

at the same time, care is taken in the firing to place those wares, such as ironstone china, *et cetera*, that require the greatest amount of heat, in the hottest portion of the kiln. As has already been stated, no kind of earthenware can withstand the direct action of the flame, especially that from a coal fire; the wares are, therefore, always inclosed in seggars, while the comparatively low temperature at which the wares are baked admits of a great economy of space, the individual pieces being packed closely. The seggars are

arranged in the kiln in columns or bungs after the manner described under *Porcelain*. The temperature of the biseuit kiln ranges from 90° to 100° Wedgwood. The following tabular statements will show the approximate number of bungs and seggars contained in the biseuit kilns at each firing. It must, however, be observed, that the bracket mentioned in the table is not general throughout the Staffordshire Potteries, but has been successfully used for many years by Messrs. COPELAND in their kilns:—

No. 1.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.						
Bracket,.....	containing	39 bungs	of ovals,.....	13 high,	or 507 seggars.	
Arches,.....	"	8	" 16 in. ovals	22 "	or 176 "	
First ring,.....	{	" 15	" ovals	}	26 "	or 624 "
		" 8	" 14 in. "			
		" 1	" 16 in. "			
Second ring,.....	{	" 3	" 20 in. 23 high	}	or 312	"
		" 5	" 18 in. 23 "			
		" 1	" 16 in. 24 "			
		" 1	" 14 in. 26 "			
		" 3	" ovals 26 "			
Third ring,.....	{	" 5	" ovals 30 "	}	or 326	"
		" 1	" 18 in. 28 "			
		" 4	" plates 37 "			
Middle ring,.....	{	" 3	" ovals 31 "	}	or 237	"
		" 1	" 14 in. 30 "			
		" 3	" plates 38 "			
Number of bungs,.....		101	Number of seggars,.....		2182	

No. 2.—SMALL OVEN—Dimensions, 15 feet diameter; 14 feet 6 inches high.							
Bracket,.....	containing	40 bungs	of ovals,.....	13 high	or	520 seggars.	
Arches,	"	8	" 16 in. ovals,...	24 "	or	192	"
First ring,.....	{	" 20	" ovals	} 29	"	or 725	"
		" 5	" 14 in. ovals				
Second ring,	{	" 2	" 20 in. ovals 22 high	}		or 234	"
		" 5	" 18 in. ovals 23 "				
		" 1	" 16 in. ovals 23 "				
		" 2	" ovals 26 "				
Third ring and middle,	{	" 1	" 16 in. ovals 26 "	}		or 220	"
		" 1	" plates 34 "				
		" 4	" ovals 27 "				
		" 2	" 14 in. ovals 26 "				
Number of bungs,.....		79	Number of seggars,.....		1444		

No. 3.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.						
Bracket,	containing	40 bungs	of ovals,	13 high	or 520 seggars.	
Arches,	"	8	" 16 in. ovals,....	24 "	or 192 "	
First ring,.....	{	" 20	" ovals	} 29	" or 725	"
		" 5	" 14 in. ovals			
Second ring,	{	" 8	" 18 in. ovals 29 high	} 29	" or 386	
		" 2	" 20 in. ovals 29			
		" 3	" ovals 32			
Third ring,	{	" 9	" ovals 33	" 41	" or 379	"
		" 2	" plates 41			
Middle ring,	{	" 5	" ovals 34	" 42	" or 212	"
		" 1	" plates 42			
Number of bungs,		103	Number of seggars,....		2414	

The mode of constructing the *seggars* for firing the fine earthenware is shown at Fig. 484GG. The marl, after beating out by the bat, *a*, upon the iron or stone slab, *b*, is cut to the required height of the seggar, and wrapped round the wooden drum or shape, *c*; the necessary thickness of clay to form the bottom of the seggar having previously been placed on the wooden board, upon the whirler, *d*, the workman now unites

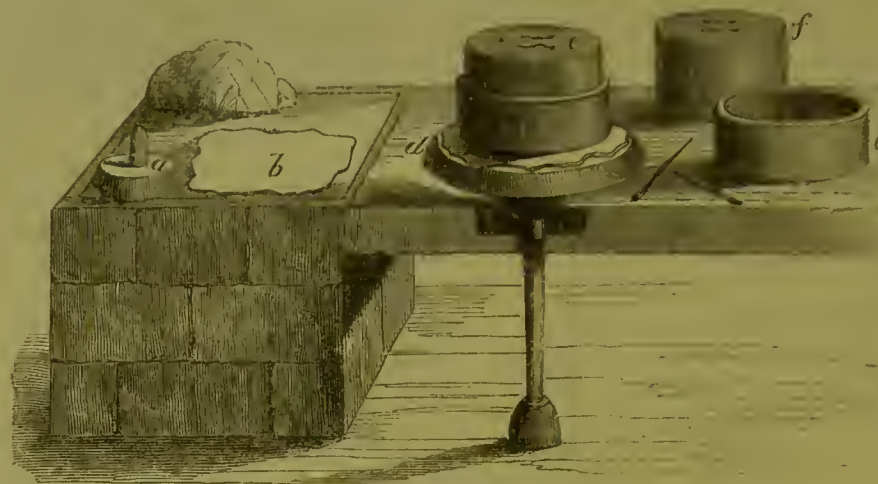
the edges of the sides together by moisture and subsequent kneading of the fingers; the bottom mass is also trimmed round, and luted up into the side in the same manner, the operation being assisted by the rotatory motion imparted by the left hand to the whirler, *d*. The seggar, after the withdrawal of the drum, is shown at *e*, and the drum at *f*. The composition forming the mass of the seggars is as follows:—

Various grey and black marls from the coal-beds mixed together with the addition of from twenty to twenty-five per cent. of coarsely-crushed old biscuit

seggars, these proportions depending upon the plasticity or porousness of the marls used.

In firing earthenware, that quality of coal is selected

Fig. 484iii.



which produces a long flame, and is not of a eaking character. The heat is moderated at first until the furnace and its contents have gradually been raised to a red heat; the temperature is then increased, the draught entering from below, and regulated by the opening or closing of the lid. The state of the biscuit is ascertained by the introduction of hollow balls of red clay, bored through on two sides, to enable their removal from the kiln—the degree of color produced affording a clue to the state of the furnace. These balls or watches become first pale-red, and after passing through several tints become red-brown; at which stage those varieties of earthenware equal in quality, or nearly allied to *iron-stone* ware, are sufficiently fired. The softer varieties are fired when the tests appear slightly tinged with dark-red. The firing in the biscuit kiln occupies about forty to forty-eight hours, the average amount of coal consumed varying from fourteen to eighteen tons, according to the size of the kiln.

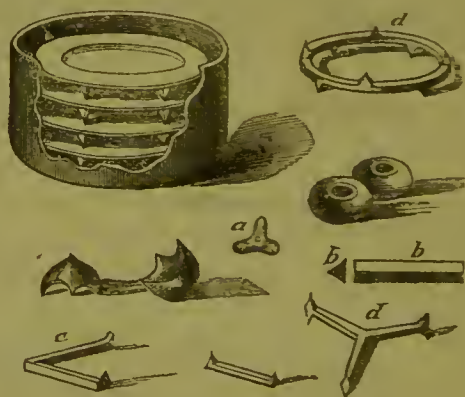
The kilns employed for the after-operation of glazing are of the same construction, but somewhat smaller than the biscuit kiln; the temperature of the furnace for burning the glaze being ascertained by the introduction of balls of clay, previously coated with glaze, into the chamber, and which assume progressively the same changes of color with the heat of the furnace. Frequently the trials from the most successful bakings are preserved in order to use them for the purposes of comparison in future operations of the same kind.

Flat pieces, such as plates, *et cetera*, are separated from each other in the seggars by small pointed supports or rests, made of hard baked clay or earthenware, called *cockspurs*, *stilts*, *triangles*, *et cetera*, as shown in Fig. 484ii; those as *a a*, *b b* being fixed into separate holes made in the side of the seggars, the plate resting upon the edges of the prominent portion, rim downwards, or, as is the case with hollow

wares, separated one from the other by the triangle *c* or *d*.

The extent and importance to which the earthenware and pottery manufactures of England have risen,

Fig. 484ii.



can only be estimated by taking the approximate returns of material used and goods manufactured over a given time, in one of the principal localities—such as the Staffordshire potteries—and which may be taken as follows:—

The total quantity of *pottery material*—such as Cornish stone, flint, kaolin, china clay, pool clay, felspar, *et cetera*—used in the various departments of manufacture in the Staffordshire potteries, during the year 1859, is estimated at not less than two hundred and twenty thousand tons; the manufactured ware sent out of the district during the same period, reaching over one hundred and ten thousand tons, which, taken at an average value of twenty-five pounds per ton, will give the enormous sum of two millions five hundred thousand pounds sterling.

Glaze.—In the composition of the glaze the following substances are used in greater or less proportions:—Felspar or Cornish-stone, flint, sand, borax, soda, tincal, boracic acid, crystal glass, minium, litharge, white lead, borate of lime, china clay, carbonate of lime, smalt; the proportions of which differ considerably, partly on account of the variable nature of the body, and partly according to the requirements of the ware, whether white, printed, or painted. The *glaze* is, however, always white, and contains lead, alumina, and soda. Minium and the preparations of lead exert a softening action, while the oxide of cobalt, used in very small proportions, rarely exceeding one-thousandth part, is for the purpose of imparting a delicate blue tinge to the glaze, and counteracting the yellow color of the body of the ware. The essentials of a good glaze are transparency, absence of color, sufficient hardness to resist abrasion, and the property of expanding by heat in nearly the same ratio as that of the body of the ware. The various ingredients are mostly fused together or fritted, and afterwards ground, sieved, and purified, as described, to free the slip from iron to form the glaze. When melted with borax or boracic acid and soda, it is a perfectly transparent green color; with tincal it is impure in color, and of a dirty-brown. The preparations of lead do not always enter into the composition of the frit, but are added to the glaze in the grinding process, with the stain also finely ground. These materials being formed into a thin water fluid, the process of glazing is the same as that described under *Porcelain*. Subjoined are several mixtures for glazes:—

RAW GLAZES.

Common Cream Color Glaze.

Cornish stone	150
Flint	35
Borax	4
White lead	300

Rockingham Glaze.

No. 1.

Red lead	42
Cornish stone	6
Flint	4½
China clay	4½
Manganese	6

Ground finely for use.

No. 2.

White lead	60
Cornish stone	6
Flint	18
Red marl	6
Manganese	10

Ground finely for use.

No. 3.

Red lead	100
Cane marl	2
Cornish stone	15
Flint	20
Manganese	15

Ground finely for use.

Yellow or Saffron Glaze.

Under glaze yellow color	10 lbs.
White lead	20 lbs.

Very finely ground.

Add to which 20 quarts of cream color glaze—4½ lbs. per quart—well sifted together.

Chrome Green Glaze.

Chrome oxide—green	2 lbs.
Flint glaze	4 lbs.

Ground for stain.

Add to which 48 quarts of printed glaze—28 oz. per pint—and well sift together.

Dessert Green Glaze.

No. 1.

White lead	3 lbs.
Calcined copper	3 lbs.
Flint glass	1½ lbs.
Flint	2 lbs.

Finely ground together. And mix—

Of the above	4 quarts.
Printed glaze	12 quarts.
Cream color, ditto	9 quarts.
Earthenware slip	3 pints.

Well lawned together.

No. 2.

Calcined copper	10 lbs.
Cobalt calx	1 lb.

Ground for color.

White lead	23 lbs.
Flint	15 lbs.
Blue clay	3 lbs.

Ground finely.

And to the above compounds add—

Printed glaze	36 quarts.
Cream color glaze	36 quarts.

No. 3.

Calcined copper	3 quarts.
Ground finely; 29 ounces per pint.	
Cream color glaze	20 quarts.
39 ounces per pint.	
Printed glaze	10 quarts.
29 ounces per pint.	

Black Glaze.

No. 1.

White lead	50
Cornish stone	20
Flint	10
China clay	7
Manganese	10

Ground for dipping.

Body as for lustre body.

No. 2.

Red lead	25
Cornish stone	10
Flint	5
Red marl—sifted	5
Manganese	2

Ground as before.

No. 3.

Cream color glaze	20 quarts.
2½ pounds per pint.	
Cobalt blue	6 lbs.
Dark red or lustre body to be used with this glaze.	

Royal Blue Glaze.

The same glaze, used upon white body, produces a fine royal blue glaze.

For lighter tints, according to the quantities of stain employed.

FRITTED GLAZES.

Cream Color Glaze.

	I.	II.	III.	IV.
Cornish stone	180	200	—	50
Flint	60	50	50	80
Flint glass	50	75	50	—
White lead	600	350	200	260
Frit	—	—	100	—
China clay	—	—	—	45
Whiting	—	—	—	45
Frit composed of Cornish stone	20	} Calcined in 1½ gloss oven.		
Frit composed of soda	1			

PAINTED WARE GLAZES—FRITTED.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	100	180	80	90	40	50	120	190	120
Felspar	—	—	—	—	40	—	—	—	—
Flint	60	100	70	5	—	35	70	20	60
Lynn sand	—	—	—	—	30	—	—	—	—
Whiting	25	—	—	—	—	40	30	30	80
Chalk	—	—	25	—	15	—	—	—	—
Tineal	—	120	—	—	—	—	—	—	—
Borax	70	—	75	65	60	100	75	60	120
China clay	10	10	—	25	—	30	10	—	30
White lead	60	—	—	—	—	—	—	—	—
Red lead	—	—	—	—	—	—	30	—	—
Soda	—	—	—	25	—	—	10	15	20

Fritted in kiln, and mixed as follows:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	60	—	100	150	160	35	75	100	180
White lead	60	100	100	200	160	45	60	—	120
Whiting	—	80	—	80	—	—	—	—	—
Flint	—	—	—	80	—	35	—	—	70
Frit	500	300	300	180	300	240	500	300	300

Others as follows:—

	Frit.	
	I.	II.
Cornish stone	100	100
Flint	75	—
Whiting	50	35
Borate of lime	150	100
Soda	25	—
China clay	25	15
White lead	25	30

Fritted in kiln, and mixed as follows:—

	I.	II.
Cornish stone	150	35
White lead	100	60
Flint	50	30
Frit	300	250

Another glaze as follows:—

Felspar	30	Boracic acid	35
Flint	20	Soda	35
Whiting	20	China clay	15

Fritted in kiln, and mixed as follows:—

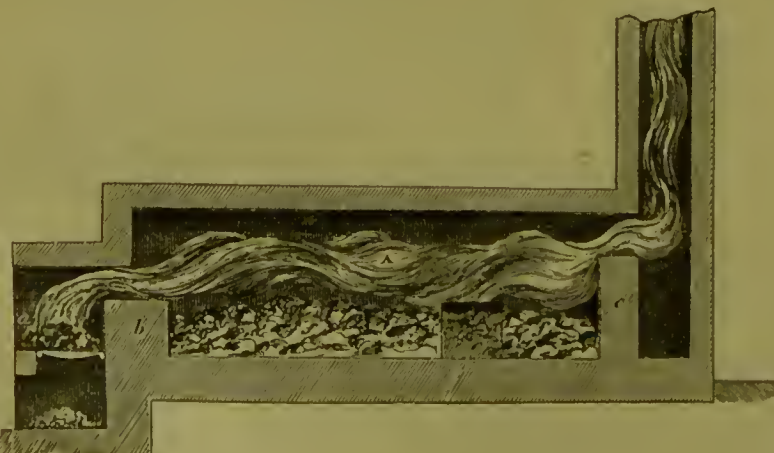
White lead	120	Felspar	150
Whiting	40	Frit	60
Flint	60		

To every charge of 600 pounds weight of the above glazes, about three ounces of cobalt blue are mixed to stain, but varied according to the color of the body.

Drab, turquoise, buff, and other fancy bodies, are dipped into glazes such as are here given; or sometimes into mixed glazes, varying between the common and the best.

The furnace for preparing the frit is shown at A—Fig. 484II. *a* is the fireplace, the flames passing over

Fig. 484II



the bridge, *b*, into the body of the furnace, *A*, where they are reverberated upon the surface of the fritted

mass, *ff*, and finally escape over the bridge, *c*, into the chimney, *d*. The frit is withdrawn from the kiln in its molten condition by the opening, *e*, and thrown or run into cold water. This aperture likewise serves for the recharging of the oven, and is closed during firing.

When the dipped biscuit has become sufficiently dry, the glaze is burnt in, being placed in seggars similar to the biscuit seggars, and glazed on the inner surface, to prevent absorption during firing of a portion of the basic ingredients of the glaze, particularly oxide of lead, by which the glaze upon the ware would be rendered rough and deficient in lustre. The pieces are separated from each other by contrivances similar to those already described under *Firing*. The marks caused by the points of contact are easily discernible in the earthenware of commerce. These little inequalities are afterwards removed by females from the ware by sharp steel dressing-tools. The junction of every two seggars in the *bung* is luted with clay to make a perfectly secure mass.

Firing.—The time occupied by the firing of the gloss or glaze kiln is about sixteen hours, and consumes from five to seven tons of coal, according to the size of the kiln, the temperature of which is ascertained by the progressive changes in color assumed by balls of red clay coated with glaze, and introduced for that purpose; but it is usual to preserve these trial balls from the most successful firings for comparison in future operations of the same kind.

Printing.—Although, from the nature of the body, it would be inappropriate to devote the same expense to the decoration of earthenware as to that of porcelain, the former very generally receives ornamentation either with the brush or by printing, and is likewise to a great extent decorated with metallic lustres. The process of printing consists of two parts—first, the production of an impression upon thin paper in a suitable ink, and then transference of the ink upon this paper to the surface of the biscuit. The

vehicle which serves as the preparation for embodying the necessary colors, is a composition formed of boiled

linseed oil, resin, tar, and oil of amber, and which becomes, when mixed with the colors, sufficiently liquid for use by spreading out upon a hot iron plate. In the selection of tints, those only must be chosen which, in chemical properties, are compatible with the character of the glaze, the temperature of the kiln, *et cetera*. Cobalt blue, manganese black, and chromium green, are very common colors, and then various proportions of these, generally incorporated with the ink for the following colors, are here given:—

UNDERGLAZE, PRINTING, AND PAINTING COLORS FOR EARTHENWARE.

Yellow.

Lead and tin ash .. 4 parts.	} Mix well together, and calcine at a gentle heat in a glazing oven; to undergo a second calcination at a higher temperature in the same oven.
Antimony .. 1 part.	

Orange.

Antimony .. 3 lbs.	} Calcination as above.
Litharge .. 3 lbs.	
Lead and tin ash .. $\frac{1}{2}$ lb.	
Ochre calcined .. 3 oz.	

Fine Brown.

Chromate of iron .. 1	} Calcine only once.
Chromate of lead .. $\frac{3}{4}$	
Calcined sienna .. 2	
Oxide of zinc .. 3	

Brown.

Oxide of manganese .. 4 lbs.	} Well calcined.
Green oxide of chromium $1\frac{1}{4}$ lbs.	
Cornish stone .. 4 lbs.	

Yellow Green.

Flint glass .. 4 lbs.	} Calcined at biscuit oven heat, and well pounded, washed with boiling water until clear, and calcined a second time.
Whiting .. $2\frac{1}{2}$ lbs.	
Green oxide of chromium $1\frac{1}{2}$ lbs.	

Yellow Green.

Green oxide of chromium 3 lbs.	} Calcined together.
Yellow color .. 3 lbs.	
China clay, burnt at biscuit heat .. 2 lbs.	
Fine sand .. 2 lbs.	

Blue Green.

Green oxide of chromium 10	} Calcined together in biscuit oven.
Oxide of cobalt .. 2	
Flux composed of equal parts of borax and flint .. 15	

Rose Color Pink.

Oxide of tin .. $2\frac{1}{4}$ lbs.	} Calcined in biscuit oven.
Whiting .. 1 lb.	
Green oxide of chromium $\frac{1}{2}$ oz.	
Cornish stone .. 6 oz.	

Purple.

To 15 pounds of rose color pink add 1 pound of cobalt calx and $1\frac{1}{2}$ pounds of fine sand. These proportions may be varied according to tint required.

Black.

Oxide of chromium .. 6 lbs.	} Calcine in glazing oven.
Calcined manganese ore 9 lbs.	
Cobalt calx .. 7 lbs.	
Gold litharge .. 10 lbs.	

Black.

Calcined chromate of iron .. 12	} Calcine together.
Cobalt calx .. 1	

Blue for flowing.

Black prepared oxide of cobalt 12 lbs.	} Calcine in glazing oven.
Flint glass .. 4 lbs.	
Oxide of zinc .. 2 lbs.	

The above for strong color, to be reduced for weaker tints by a flux composed of equal parts of flint glass and flint.

Blue for ordinary printing.

Blue cobalt calx .. 1 lb.	} Grind for use.
Cornish stone .. $1\frac{1}{2}$ lb.	

Or a mixture of half stone and half flint.

May be reduced to 1 part of blue and 5 parts of fluxing material. The fluxing of these blues are much varied by manufacturers.

Of late a manufacture has been introduced of a *flowing blue* and other colors, giving a softness to the coloring upon fine earthenware, which has been much esteemed. This is produced by what is termed a *flow*, introduced into the seggar or fire-case; a few of the *flows* are here given:—

Quick lime .. 5	} Well mixed together and sprinkled carefully round the bottom edge of the seggar.
Salt .. 2	
Nitre .. $\frac{3}{4}$	
Borax .. $\frac{1}{4}$	

Again—

Whiting .. 4	} Mix and use as above.
Salt .. $2\frac{1}{4}$	

Again—

Nitre .. 4	} Mix and use as above.
Salt .. 1	
Bone .. $1\frac{3}{4}$	
Alum .. $1\frac{1}{4}$	

Again—

Quick lime .. 25	} Mix and use as above.
Chloride of ammonium .. $2\frac{1}{2}$	
Red lead .. 5	

These and various other mixtures are introduced for the like purposes.

But the most admired is the *pink color*, obtained from acid stannate of oxide of chromium, with stannate of lime, and very extensively applied to decoration. This pigment, originally a profound secret, has been chemically decomposed by MALAGUTI, from the results of which analysis, a practical mixture has been prepared with great success, more especially at Montereau in France. Analysis gave—

Oxide of tin—Sn O ₂ ..	78.31
Lime ..	14.91
Silica ..	3.96
Alumina ..	0.95
Water ..	0.61
Oxide of chromium ..	0.52
Chromate of potassa ..	0.26
Potassa and loss ..	0.48

100.00

and from this has been deduced the following mixture:—

Oxide of tin ..	100
Chalk ..	34
Oxide of chromium ..	1 to $1\frac{1}{4}$
Chromate of potassa ..	3 to 4
Silica ..	5
Alumina ..	1

The mixture and preparation of the oil for receiving the colors is as follows:—Mix together—

Old linseed oil 2 gallons
Rape oil 1 quart

To which add—

Red lead 2 ounces
Flowers of sulphur 1 ounce

Place the mixture into an iron cauldron suspended over a clear fire until it begins to boil; the scum which rises is then ignited and burnt off, a close-fitting iron disc covered with flannel being used to extinguish the flames. When the scum is consumed, add gradually two ounces more of red lead, and let the scum be burnt off a second time as it rises. As soon as the oil is sufficiently boiled to become adhesive and stringy to the finger, mix with the mass—

Burgundy pitch 2 pounds
Spirits of tar 1 quart
Gum mastic 1 ounce

These ingredients, previously warmed together in a pan, are added very gradually to prevent ebullition, the oil being removed from the fire for that purpose. After the whole has been stirred together for fifteen minutes, it is strained off through a hair sieve and allowed to cool for use. Other oils are sometimes used, but all possess similar powers to the above.

Printed colors are seldom transferred upon the glaze, but are generally printed upon the biscuit, in which case the addition of a flux is not essential, its place being supplied by the glaze.

The process of applying the pattern to the biscuit is as follows:—The design is engraved upon a copper plate in a broad open style, to prevent the lines from running into each other, and forming a blurred appearance. Those portions intended to produce a shaded effect are cut deeper to retain more color. The ink, which is first spread over the surface by a printer's dabber while the plate is on the hot stove, is, after the pattern is well filled in, removed by passing a knife over the surface and wiping with the boss to clean the surface from superfluous oil. The impression is then taken from the plate much after the manner of ordinary copperplate printing, a similar press being employed.

The paper upon which the impression is taken is of a fine, soft, uniform, and durable nature, much about the consistency of tracing paper, and previous to use is saturated with soft soap and well damped. This particular paper is manufactured only in the district under FOURDRINIER's patent. In this manner the various patterns are printed closely upon the paper to economize space, their size being proportionate to that of the ware intended to receive them. After the patterns are separated by scissors, they are placed with the printed side next the ware, and rubbed down upon it with the end of a firmly bound roll of flannel. This is done gently at first, and afterwards more forcibly, until the ink is transferred to the surface of the biscuit. The ware is then plunged into water, when the paper is easily removed after a short time by the gentle application of a sponge. Accurate impressions by this

process can only be obtained when both the surface receiving the transfer and that of the paper bearing the impression are flat. In ordinary manipulation the paper has to be applied to a curved surface with a certain amount of pressure to avoid the creasing, and this, unless carefully performed, is apt to cause a doubling up and distortion of the pattern.

From the circumstance that each differently shaped piece of the same pattern, and each piece of the same shape, but of different size, such as plates, *et cetera* require a separate engraved copperplate, this becomes a very expensive operation—the process of engraving a set of plates ranging from eighty to one hundred and fifty pounds for the full service, even of the most simple design. This expense is again increased by the unequal wear and tear of the plates, and consequent frequent reproduction of the pattern necessary for a particular piece, such as a plate or saucer, the number of which printed, in proportion to other pieces, such as dishes, vegetal covers, *et cetera*, is very large, so much so that often a thousand plates of a pattern are thrown off against one cover or dish.

A very important change in the manipulation as regards the whole process of preparing the design, regulating the sizes, engraving, and reproducing the plates, has been patented by Mr. WILLIAM MACKENZIE of Glasgow; and the improvements which he proposes are so applicable to the process of decorating clay wares, as regards not only the exactitude and simplicity of the process, but also the economy of production it develops, that ultimately no doubt it will entirely supersede the present expensive system already described. This process may be briefly described as follows:—The intended design is first of all either engraved upon copper or drawn upon stone, of such a size as to fit one of the pieces of the set, say a plate of medium size, and from which an impression in transfer ink is taken, and by a peculiar process transferred to the prepared surface of an elastic sheet. This sheet is afterwards placed on a frame and extended equally in all directions, until the design is accurately brought to the scale required for the plate next in size; while in this extended condition, the pattern is retransferred to the prepared surface of a zinc plate by the ordinary process of lithographic printing. The zinc plate, which has now received the pattern upon the enlarged scale, accurately corresponding in every particular with the original, line for line, is after a little further preparation subjected to the engraving process, *electricity* taking the place of *manual* labor, and in the course of six or eight minutes the plate is finished, presenting all the gradation of depth and tone of the original, only of a different size. The subsequent operation of printing may be greatly simplified, by a chemical preparation of the surface of the zinc, causing a reaction to take place with the oily nature of the ink which then only attacks the engraved parts, and leaves the surface of the plate perfectly free from the ink or grease of the filling-in process. The facility and cheapness with which particular designs can be reproduced, as also the extreme accuracy and uniformity of outline obtainable in repeated patterns, constitute the chief recommendations of this patented process.

After printing, the biscuit cannot immediately be glazed, the oily nature of the mordant or color-vehicle preventing the absorption of the glaze by such portions of the ware as are covered by it. It therefore becomes necessary to destroy this oily consistency by heat before the glaze is applied—a process technically termed *hardening on*. The temperature is raised only sufficiently to burn the oil without producing any chemical action on the color. An oven sometimes employed for this purpose is of the size of a moderate room, quadrangular in shape, and arched above. The room, packed as closely as possible with wares, is luted up, and a small iron box or movable wind furnace, called a *davy*, introduced through a trap in the floor. At the four corners of the chamber, pipes protrude through the roof, and descend nearly to the floor of the room, acting as so many flues to distribute the heat by drawing the flame from the burning cinders to the sides of the chamber. A short pipe is placed in the centre of the roof, the outside aperture of which, furnished with a valve, is connected to those of the four others by levers in such a manner that when the centre one is closed the others are opened, and *vice versâ*. After the chamber is fired, this centre valve is kept closed by a rod of lead, the four others being open. The heat from the stove gradually increasing from below upwards, until the temperature of the chamber is raised to the heat at which the leaden rod melts, receives a sudden check by the opening of the centre valve, and the draught being cut off by the closing of the four side valves, the fire is soon extinguished. Other forms of *hardening on* kilns are used for the purpose of destroying the oil; but by such an arrangement as that just described, the most accurate regulation of heat is attained, and at very small expense, the stove consuming the cinders and waste from the baking kilns. The operation of glazing then proceeds in the usual manner.

When the printed pattern is applied to the ware above the glaze, the mordant receives a larger proportion of gum mastic; but where enameling colors are used for the muffle, a *size* is applied to the surface of the glaze, composed of spirits of turpentine, with a small portion of gum mastic dissolved in it; sometimes rosin and sugar of lead being added.

Decoration.—The ornamentation of fine earthenware by the hand and brush is practised only for the production of a certain class of designs, such as flowers, leaves, garlands, dots, *et cetera*, and executed by *artistes* expressly trained for that purpose, and each excelling in a particular branch of ornamentation, such as flowers, foliage, scrolls, and the like.

In the preparation of the several tints used in the higher decorations of porcelain and fine earthenware, great care is required to regulate the exact degree of heat to which the biscuit is raised, with a view to the development of the required tints in the several firings through which the wares pass. The following is the mode of preparation of the various colors and their compounds:—

PREPARATION OF ENGLISH AND FRENCH ENAMEL COLORS FOR PAINTING PORCELAIN AND EARTHENWARE.—*English.*—The beauty and success of the hues in the firing depend in a great measure upon

the purity of the oxides from which they are prepared. They should, therefore, in manipulation always individually represent the same body both in chemical composition and molecular arrangement, so as to be subject to the same changes under similar circumstances. For example, the oxides of iron, chromium, purple of cassius, gold, platinum, *et cetera*, although they may be perfectly pure, are very difficult to work if their precipitation has taken place too rapidly, or at an improper temperature. Under the name of vitrifiable colors are generally classed pigments, without distinguishing between the coloring matter and its base, it being generally supposed that the two substances unite chemically by fusion, and form a homogeneous base; this is only the case, however, in some instances, as, for example, with the oxides of cobalt and the oxides of copper; while in others, on the contrary, as the oxides of chromium, the oxides of iron, *et cetera*, the base is only the vehicle which contains the color, and which serves to fix it upon the surface it is applied to. In considering, therefore, the preparation of the colors properly so called, the *oxides* will be given distinct from the bases or fluxes by which they are fixed upon the surface of the wares.

Oxides.—Amongst the *simple oxides* may be classed—oxide of chromium, oxide of iron, oxide of uranium, oxide of manganese, oxide of zinc, oxide of cobalt, oxide of antimony, oxide of copper, oxide of tin.

Amongst the *oxides mixed with earthy matter*, may be classed chromate of iron, chromate of baryta, chromate of lead, chloride of silver, purple of cassius, umber, sienna, and red and yellow ochres. The mode of preparation of these various materials causes the greatest difference in the quality of the colors into which they severally enter.

Sesquioxide of Chromium—*chrome green*— Cr_2O_3 —is generally prepared for potters' use by calcining a mixture of equal parts of chromate of potassa and sulphur in a close earthenware crucible at a red heat, the green mass which is produced being well washed to dissolve out the sulphate and sulphide of potassium. The oxide of chromium which remains is further purified by repeated elutriation.

GUIGNET has recently discovered—1859—a new method of preparing oxide of chromium for coloring purposes. A mixture of three parts boracic acid and one part bichromate of potassa is calcined at a temperature of about 932° . An evolution of water and oxygen gas takes place, and there is formed a double borate of sesquioxide of chromium and potassa. This salt, which is stable at the ordinary temperature, is decomposed by water, giving biborate of potassa and sesquioxide of chromium; the latter in the nascent state combines with water, and forms a hydrated sesquioxide of a remarkably fine color. This is separated from the biborate of potassa by decantation and washing, leaving a chrome green of a very solid and brilliant description.

Sesquioxide of Iron— FeO .—This is prepared by the calcination of green vitriol, upon the purity of which the brilliancy of the color in a great measure depends. For the calcination a thick cast-iron vessel or earthenware retort is required. During the operation the

sulphate must be kept continually stirred with an iron rod; the powder at first assumes a yellow hue, passing into brown, and finally a greenish brown, which upon cooling changes to red, a sulphuric acid vapor being eliminated during the process, which continues until the powder is reduced about two-thirds of its volume. It is then taken from the fire and allowed to cool, the red deposit being thoroughly washed from all impurities until the water exudes from the filter perfectly tasteless. A red color of a more brilliant tone is obtained from iron by calcining together a mixture of equal parts of sulphate of iron and sulphate of potassa in a crucible slowly up to a dull-red heat. The pigment is afterwards washed with hot water to remove all impurities.

Alum may also be substituted for the sulphate of potassa, or sienna combined with sulphate of potassa may be substituted for the sulphate of iron; but whichever process is adopted, the preparation of the red oxide requires very careful manipulation.

Oxide of Uranium— U_3O_8 —*Uranoso-uranic oxide*—is prepared from pitchblende, which contains from forty to ninety-five per cent. of oxide, and certain proportions of sulphur, selenium, phosphoric acid, lime, magnesia, alumina, silica, manganese, vanadium, arsenic, bismuth, antimony, zinc, tin, lead, iron, cobalt, nickel, copper, and silver. The powdered pitchblende is dissolved in warm nitrohydrochloric acid, and, after all action has ceased, the excess of acid is expelled by evaporation. The residue being heated with a small quantity of hydrochloric acid and water, the solution is filtered from the sulphur and silica, and also from chloride of lead and silver. The arsenic, lead, and copper, with bismuth and tin, are then precipitated from the filtrate by sulphide of hydrogen, and the solution again filtered and boiled, nitric acid being added to convert the protoxide of iron into sesquioxide, which is precipitated by super-saturating the liquid with a large quantity of carbonate of ammonia; this throws down the iron, together with any lime that may be present, and the greater part of the cobalt and zinc oxides, retaining in solution the uranic oxide, together with portions of the cobalt and zinc. The filtrate is then boiled as long as ammonia continues to be evolved, by which means the three metallic oxides, cobalt, zinc, and uranium are precipitated, with the exception of a small quantity of cobalt, which colors the liquid red. The precipitate is collected upon a filter and afterwards washed, dried, and ignited, till its yellow color changes to a blackish-green; it is lastly digested for several hours with cold dilute hydrochloric acid, which dissolves the two compounds of cobalt and zinc, and leaves the pure uranoso-uranic oxide undissolved.

Manganese—Binoxide of Manganese— MnO_2 .—One of the commonest ores of manganese is found in a state of great purity in Sweden and other parts. The purest variety is that known in commerce under the term of pyrolusite, or black oxide of manganese.

Sesquioxide of Manganese— Mn_2O_3 .—may be obtained by heating pure binoxide of manganese in a crucible to redness until it ceases to evolve oxygen; or by exposing protonitrate of manganese to a red heat, the sesquioxide remains as a black powder.

Protoxide of Manganese— MnO .—may be economically prepared by heating chloride of manganese to redness with twice its weight of carbonate of soda and a little chloride of ammonium, exhausting the fused mass with water when cold; the residuum is protoxide of manganese.

Oxide of Zinc— ZnO .—is obtained by distilling zinc from clay retorts into chambers through which a current of air is maintained, the volatilized metal burns at the high temperature to which it is exposed, and the oxide is deposited in a series of condensing chambers. The hydrated oxide may be obtained by precipitation from the solutions of the salts of zinc by the addition of an alkali. An excess of the alkaline liquid readily solves the oxide.

Oxide of Cobalt, the ores of which, after grinding and roasting, to drive off as much as possible the excess of arsenic and sulphur, are dissolved in hydrochloric acid, sometimes with the addition of a small quantity of nitric acid. The copper, lead, silver, arsenic, antimony, &c., are precipitated by sulphide of hydrogen, and to the filtered solution carbonate of lime is added in the form of chalk, by which all the iron, alumina, and a trace of cobalt are thrown down, the nickel and cobalt remaining in solution. To this solution, which must be hot and neutral, a solution of bleaching powder is added in sufficient quantity to precipitate the cobalt, and the menstruum is then well boiled to remove the chlorine as fast as possible. The oxide of nickel is afterwards precipitated from the filtrate by the addition of hydrate of lime, and ebullition.

Oxide of Antimony— Sb_2O_3 .—This is found native as white antimony ore, and may be prepared artificially by boiling pulverized antimony with moderately strong nitric acid, until it is converted into a white powder, which is freed from the excess of acid by repeated washings in boiling water. One part of powdered antimony digested with two parts of aqua-regia and four parts of water, yield 96.6 parts of antimonic oxide. A mixture of seventy-four parts antimony, thirty-nine of nitrate of potassa, and thirty-four of bisulphate of potassa is projected into a red-hot crucible, the ingredients being added rapidly one after another. The resulting mass, after boiling first with pure water, then with water containing a small quantity of sulphuric acid, and afterwards with pure water, will be the antimonic oxide.

Oxides of Copper—*red oxide of copper*— Cu_2O .—is prepared by heating one hundred parts of blue vitriol with fifty-seven parts of carbonate of soda until the water of crystallization is expelled. The residuum is afterwards mixed with twenty-five parts of copper filings, and the mixture finely stamped into a crucible. It is then exposed to a white heat for about twenty minutes, and after cooling and pulverization, the mass is well washed with water. This process yields about fifty parts of fine colored red oxide of copper.

Black Oxide of Copper— CuO .—The red oxide passes into the protoxide of copper when heated in the air; or it may be conveniently prepared by exposing a mixture of one part of copper filings and two parts of the deliquesced nitrate of copper to the air until the whole is converted into a basic salt, and then igniting

the salt. It communicates a green, and sometimes a blue tint to vitreous compounds; and DAVY has shown that it is the basis of certain colors used by the ancients, which had been supposed to contain cobalt.

Oxide of Tin— SnO_2 —may be prepared by treating the metal with nitric acid. In its most concentrated form the acid does not immediately act, but will violently effervesce with heat upon the addition of a few drops of water. The peroxide of tin remains in the form of a white insoluble powder, and is purified by washing with boiling distilled water, and drying at a dull-red heat.

Chrome Iron Ore— $\text{FeO Cr}_2 \text{O}_3$.—The native chromate of iron is a compound of oxide of chromium with protoxide of iron, but part of the ferrous oxide is replaced by magnesia, and part of the chromic oxide by alumina. By analysis the constituents are as follow:—

Magnesia	7.49
Iron	20.99
Oxide of chromium	59.96
Alumina	11.56
	<hr/>
	100.00

Chromate of Baryta— BaO CrO_3 —is prepared by dropping a solution of chromate of potassa into a solution of chloride of barium; the yellow precipitate must be well washed, and is as insoluble in water as the sulphate of baryta.

Dichromate of Lead— $2 \text{PbO}, \text{CrO}_3$ —*chrome red*—may be obtained by boiling oxide of lead, or its carbonate, with an aqueous solution of monochromate of potassa, or by digesting the neutral chromate of lead in a dilute solution of caustic potassa. LIEBIG prepared it by adding a neutral chromate to fused nitre, and washing the residuum; it is an insoluble, scarlet colored powder.

Chromate of Lead— PbO, CrO_3 —*chrome yellow*.—When chromate of potassa is added to a soluble salt of lead, both solutions being hot, a fine colored anhydrous precipitate is obtained; if the solutions are cold, the precipitate will be pale yellow, and will contain an equivalent of water.

Chloride of Silver— Ag Cl —is best obtained by adding a solution of chloride of sodium in excess to a slightly acidulated solution of nitrate of silver. The curdy precipitate of chloride of silver requires very careful washing.

FLUXES.—General Flux.

Red lead	3	} Fritted together into a perfect glass, and pounded for use.
Borax	2	
Flint	1	

Soft Lead Flux.

Red lead	3	} Ditto.
Flint	1	

White Flux.

Glass	12	} Ditto.
Borax	14	
Flint	9	
Red lead	6	

Chrome Flux.

Red lead	4	} Ditto.
Flint glass	14	
Flint	1	

Purple Flux.

Glass	16	} Fritted together into a perfect glass, and pounded for use.
Borax	10	
Lead	9	
Flint	4	

Soft Borax Flux.

Borax	4	} Ditto.
Flint glass	3	
Cornish stone	1/2	

COLORS.—White Opaque Enamel.

Flint glass	16	} Run into mass in flinted crucibles or seggars in glazing oven.
Arsenic	1 1/2	
Nitre	1	
Red lead	4 1/2	

White Opaque Enamel.

Oxide of tin	1	} Calcined in biscuit oven, and 1 1/2 of calcine added to 2 parts of general flux, and afterwards run down again in glazing oven.
Felspar	1 1/2	

Yellow.

Under glaze yellow	1
General flux	2 1/2

Orange.

Under glaze orange,	1
General flux	2 1/2

Red.

Green vitriol calcined to drive off the water of crystallization, and brought to a pale red tint, and then well washed until perfectly free from the sulphuric acid. Here great care is required to obtain the proper tint, neither too pale nor too dark.

Of this calcine take	1 1/2
General flux	2 1/2

Chocolate.

Same preparation of vitriol at the heat of a glazing oven, well washed as the foregoing, and fluxed.

Calcine	1
General flux	3

Dark Brown.

Umber	1	} Calcine together in glazing oven, well washed, and to 1 part of calcine add 2 parts of general flux.
Sienna	3/4	
Red oxide of iron	1	
Oxide of zinc	1 1/4	

Another Dark Brown.

Umber	1 part.	} Calcined in glazing kiln.
Calcined terra sienna	1 1/4 parts.	
Oxide of iron	1 part.	
Oxide of zinc	1 1/4 parts.	

To one part of the calx add three parts of general flux. Ground for use.

French Yellow Brown.

Oxide of tin	2 1/4 lbs.	} Calcine in kiln, and to 1 part of calcine add 2 1/2 parts of general flux.
Oxide of zinc	2 lbs.	
Red oxide of iron ..	1 1/4 lbs.	

Another Yellow Brown.

Oxide of tin	3 parts.	} In glazing kiln.
Oxide of zinc	2 parts.	
Oxide of iron	2 1/2 parts.	

To one part of the above add three parts of general flux.

Base for Copper Green.

Flint glass	12	} Run down in glazing oven.
Red lead	27	
Borax	9	
Flint	6	
Oxide of copper	2	

Black.

Calcined umber	1	} Calcine in kiln, and to every 4 parts add 3 parts of general flux.
Blue cobalt calx	1	
Flint glass	1½	
Red lead	1½	
Borax	1½	
Flint	1	

Another Black.

Black oxide of cobalt	2½
Turkey umber	1½
Soft borax flux	2½

Another Black.

Black oxide of copper	1 part.	} Calcined in glazing oven.
Oxide of cobalt	1 part.	
Oxide of manganese	1 part.	
White flux	10 parts.	

To four parts of the above add one and a half parts of white flux.

White Enamel.

Flint glass	20	} Run down in glazing kiln.
Red lead	5	
Nitre	1½	
Arsenic	1½	

Sometimes an addition of the oxide of tin.

Blue Green.

Base as above	10 parts.
White enamel	1½ parts.

Yellow Green.

Base	10 parts.	} Run down.
Enamel yellow	15 parts.	
White enamel	1½ parts.	

Chocolate Brown.

Croesus mentis	4 parts.	} Run at gentle heat.
General flux	12 parts.	

Deep Blue.

Flint glass	4 parts.	} Run in glazing kiln.
Red lead	1½ parts.	
Pearlash	1-16th part.	
Muriate of soda	1-16th part.	
Carbonate of cobalt	½ part.	
White enamel	½ part.	

Mat Blue.

Carbonate of cobalt	2 parts.	} Run in glazing kiln.
Oxide of zinc	2 parts.	
Borax flux	4 parts.	

To two parts of the above add one part of borax flux.

Run down at a gentle heat.

Rich Chrome Red.

Red lead	3 parts.	} Run down at a gentle heat.
Chromate of lead	1 part.	
Chrome flux	2 parts.	

Green from Oxide of Chrome.

Oxide of chrome green	3 parts.	} Calcined at high heat, and well washed.
Carbonate of cobalt	1 part.	
Felspar	2 parts.	

To one part of the above add four parts of soft borax flux. Run down.

Various tints of green obtained by the addition of enamel yellow, previously given.

FRENCH ENAMEL COLORS.

FLUXES.

No. 1.—*Rocaille Flux.*

Red lead	75	} Run down at low heat.
Sand	25	

No. 2.—*Grey Flux.*

Red lead	66	} Run down as above.
Sand	22	
Calcined borax	12	

No. 2 S.

Red lead	60	} Run down at low heat.
Sand	15	
Boracic acid	25	

No. 3.—*Carmine Flux.*

Red lead	12	} Run down as above.
Sand	33	
Calcined borax	55	

No. 4.—*Purple Flux.*

Red lead	36	} Run down as above.
Sand	14	
Boracic acid	50	

No. 5.—*Violet Flux.*

Red lead	68	} Run down as above.
Sand	5	
Boracic acid	27	

No. 6.—*Green Flux.*

Red lead	73	} Run down as above.
Sand	9	
Boracic acid	18	

FRENCH COLORS.

Dark Grey.

Carbonate of cobalt	6	} Run down at low heat.
Oxide of zinc	13	
Yellow oxide of iron	13	
Flux, No. 2 or No. 2 S	68	

Russet Grey.

Carbonate of cobalt	6	} Run down to the tint required.
Oxide of iron	3	
Oxide of zinc	3	
Flux, No. 2	88	

Black Grey.

Carbonate of cobalt	10	} Run down.
Oxide of cobalt	5	
Flux, No. 2	85	

Brown Black.

Carbonate of cobalt	16	} Ditto.
Oxide of iron	8	
Flux for greys, No. 2 or No. 2 S	76	

Iridium Black.

Sesquioxide of iridium	25
Flux for greys, No. 2	75

Dark Indigo Blue.

Carbonate of cobalt	14	} Calcined in kiln.
Carbonate of zinc	26	
Flux for greys, No. 2	60	

Sky Blue.

Carbonate of cobalt	7	} Ditto.
Carbonate of zinc	14	
Flux, No. 2	79	

Blue Green.

Oxide of chrome	50	} Calcined at a high heat.
Carbonate of cobalt	25	
Carbonate of zinc	25	

To twenty-five parts of the above add seventy-five parts of flux, No. 3 or No. 6. Ground for use.

Clear Yellow.

Antimoniate of potassa	12	} Run at gentle heat.
Carbonate of zinc	6	
Oxide of iron	2	
Flux, No. 2 or No. 2 S	80	

Jonquil Yellow.

Lead and tin ashes	8	} Mix and run down.
Calcined carbonate of soda	3	
Antimoniate of potassa	3	
Flux, No. 1	86	

Chrome Orange.

Chromate of lead	25	} Run down together.
Red lead	75	

Tranium Orange.

Oxide of uranium	25	} Run down.
Rocaille flux, No. 1	75	

Red.

Red oxide of iron, prepared from sulphate of iron by gentle calcination to the required tint.

To twenty-five parts of the above add seventy-five parts of flux, No. 2 or No. 2 S.

Sepia Brown.

Red oxide of iron	12	} Run down.
Oxide of zinc	12	
Carbonate of cobalt	3	
Flux, No. 2 or No. 2 S ..	70	

Russet Brown.

Oxide of iron	12	} Run down.
Oxide of zinc	12	
Sepia brown	3	
Flux, No. 2	72	

Various tints of green are produced from the oxide of chrome, with the addition of yellow as given.

Carmine, purple, and rose colors are from the purple of cassius, prepared by precipitating gold from the solution of aqua-regia by nitromuriate of tin; to which precipitate is added a small proportion of chloride of silver, and the flux—No. 3 for carmine, or No. 4 for purple—in proportion, according to the heat required in the process of firing, to produce a fine tint.

Purple of Cassius.

The acids used for the solution of gold for this process are, hydrochloric 1·13, and nitrous 1·41—three parts of the former to one part of the latter. Ten pennyweights of the above aqua-regia will dissolve one pennyweight of fine yellow gold. For the solution of tin, twenty pennyweights of hydrochloric acid, ten pennyweights of nitrous acid, and twenty pennyweights of pure water, dissolve in these quantities ten pennyweights of well granulated tin. The tin must be added by small pieces, each being allowed time to dissolve before more is added, and so on to saturation, when the solution, if properly performed, should assume the clear and bright color of brandy. Great care is required for the performance of these processes.

Many other forms are given by various authors, each preferring their particular methods. The solutions here described having been prepared, the processes will be now given.

Into a vessel of sufficient dimensions pour two quarts of good pure water, into which the solution of gold is to be poured, when it will, in its diluted form, assume a pale straw color; into this the solution of tin is to be carefully added, and stirred continuously with a glass spatula until the cassius is well formed, and the precipitate should be of a brilliant carmine tint. Time having been allowed for the cassius to subside, the water is to be carefully removed by a syphon, and washing continued, by changes of the water, until the cassius is perfectly free from the acids. The cassius must then be carefully collected on a filter, and, whilst in a moist state, is ready for further use.

Rose Color.

The cassius, with fifteen grains of silver and sixteen ounces of flux.

Flux.

Flint glass	4 parts.
Borax	2 parts.
Red lead	2 parts.
Flint	1 part.

To form the Cassius for Purple Color.

Gold solution	10 pennyweights.
Tin solution	20 pennyweights.

The Cassius with

Silver	10 grains.
Flux	6 ounces.

Purple flux is already given.

Fine earthenware, although chiefly confined to the *potteries* in Staffordshire, is also made in considerable quantities abroad—in France, in the neighborhood of Paris, at Bordeaux, Saargemünd, *et cetera*; in Germany, at Mettlach, near Saarbrück, and Poppelsdorf, near Bonn. Earthenware is also made at Baireuth, Aschaffenburg, Kelsterbach, *et cetera*, and at Carlsbad in Bohemia; at all of which places several kinds are produced simultaneously with the fine earthenware. The differences in the manufacture are confined chiefly to the manner of preparation of the clay, the composition of the glaze, and the ornamental decoration. At Mettlach four varieties are manufactured.

1. *Stoneware*, composed of plastic clay from the Palatinate, ground quartz from Oberwald or Berncastle, calcareous tufa from Sierk. The glaze contains lead, and the ware has a yellow tint.

2. *Yellow or Nankin-colored* earthenware, composed of grey plastic clay from Vallendar, near Coblenz, and clay from Eifel, which burns yellow. The glaze contains lead.

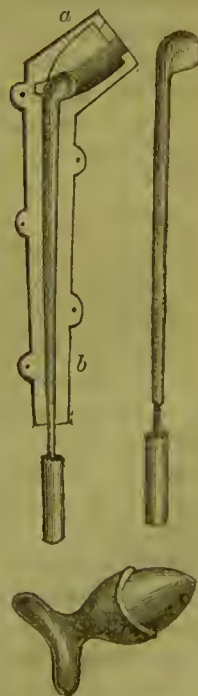
3. *Hard Stoneware*, containing plastic clay from the Palatinate, and ground quartz and gypsum from Luxemburg. The glaze a tolerably hard lead glass, containing boracic acid.

4. *Poreelain Stoneware*, containing plastic clay from the Palatinate and from Vallendar, with ground quartz and bone ashes. The glaze free from lead, and composed of borax, alkali, and felspar.

Amongst the varieties of fine earthenware may be classed the peculiar manufacture of *clay pipes*. The clay used in the construction of these requires extreme plasticity, together with a certain amount of porosity upon firing. The plastic clay found in the layers forming the basis of the clay deposit, is used without the addition of a flux, but to insure the perfect uniformity and pliability of the mass, great care is taken with the kneading and slapping processes.

The manufacture of tobacco pipes, in consequence of the immense demand for them, is one of considerable importance in the potter's art. From a prepared lump of the clay the moulder separates a number of pieces, each sufficient for the construction of a pipe, and rolls them out on a table two at a time, one in each hand, to nearly the form and dimen-

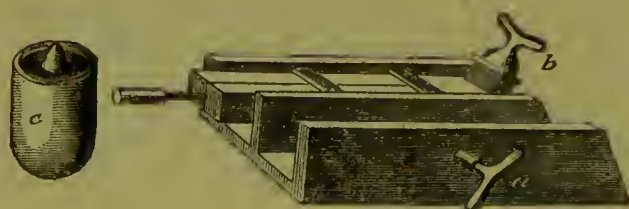
Fig. 484KK.



sions of the intended pipe, the thinner portion having rather more than the thickness of the future tube, whilst the bulbous portion at the end is somewhat less in diameter than the bowl. When these rolls have become sufficiently hardened by exposure to the air, a second workman receives them in bundles for the operation of boring the tube by means of an oiled wire mounted in a wooden handle. With his left hand he forces forward the oiled wire, whilst the thumb and forefinger support the roll, and with a kind of feeling motion guides the point of the wire very accurately along the axis of the roll. The point of the wire is rounded like a button to facilitate the operation, which is performed with surprising celerity.

The whole length of the pipe is not pierced at once, an inch being left unbored, and the unfinished pipe with the wire is placed in the half of the copper mould, *a*, *b*—Fig. 484KK—previously brushed with oil to give smoothness to the stem upon removal. The two halves of the mould, closed accurately together by means of pins, are then placed in a frame—Fig. 484LL—and the edges kept in contact by the screw vice, *a*.

Fig. 484LL.



The stem is thus shaped in the mould, together with any impress or name that may have been cut upon it. The bowl of the pipe is first roughly formed by the introduction of the finger, and afterwards completed by the insertion of the plug, *b*, into the mould. Upon opening the mould the operation of boring is completed, the small pellet of clay which precedes the wire being removed by a little hook attached to the handle of the knife used for forming the edges and bowl of the pipe, which is done by removing the superfluous clay. Finally, the rim of the bowl is formed by the small copper mould, *c*. When the pipes have been removed from the moulds, and the wires drawn out, any ornamentations not given by the pipe mould are added by means of roulettes and stamps. The pipes are then laid out to dry, the sutures removed with a sharp knife, and polished by grooved agates. When the stem of the pipe is required to be curved instead of straight, the two extremities only are supported upon the drying boards, causing the centre to sink down. The number of complete pipes produced by a good moulder will average five hundred a day, notwithstanding the number of operations each pipe has to undergo.

The white color of the pipe being an essential requisite, requires that they be fired in seggars. When the pipes are short, and there is little risk of fracture or bending, as many as possible are placed in the seggar without reference to any particular arrangement;

but for firing long pipes, ring-formed projections upon which the bowls of the pipes rest, are made on the inside of the seggars, a grooved column in the centre supporting the ends of the stems, which, when projecting above the seggar are protected by a conical lid. In London the clay-pipes noted for elegance of form are fired in a close kiln—Fig. 484MM—shown in section, and from which the flame and smoke of the fire are totally excluded. The bottom and sides of

Fig. 484MM.



the kiln are constructed of similar material with the pipes themselves, the refuse and fragments of old pipes being worked up for this purpose. This close kiln, *a*, is supported over the fire-place, *b*, by the brackets, *e*, a space of several inches being left between the sides of the kiln and the outer casing of the fire-brick, *c*, and the whole inclosed by the *hovel* of brickwork, *d*. The flame circulates freely in the intermediate space between the kiln and casing, *c*, supports being introduced at intervals to keep the kiln in its proper position, and which, being connected together by occasional apertures, serve at the same time the purposes of flues to regulate the direction of the flame. The opening, *f*, in the lining of the kiln, *c*, for the introduction and removal of the pipes, is closed during firing by an iron door luted with clay. The corresponding opening in the kiln itself is plastered

up after charging with clay and broken fragments of pipes. The pipes are supported in the kiln by rings of clay, *g g*, surrounding the sides and the central bearings, *m m*, the weight of the whole charge being distributed between the sides of the kiln and the central column, so as not to bear upon the lowest layer of pipes. These kilns vary in size, and sometimes fire a hundred gross of pipes at once. The firing lasts from ten to fourteen hours, the temperature being gradually raised to the full intensity required for baking. The fuel used is coke, and a small opening, *r*, is left in front of the kiln to enable the workman to judge of the interior temperature.

The porosity of the biscuit causes the burnt pipes to absorb water with avidity, and to adhere in a very unpleasant manner to the lips. The ends of the stems are therefore either rubbed with a mixture composed of gum, soap, and wax, or coated with resin or shellac. Sometimes they are glazed by dipping into a very fusible lead glaze; the covered ends being afterwards exposed to the flame of the furnace for about ten minutes.

Common Earthenware or Delftware is characterized by its extreme opacity, its open porous structure, and soft texture; in fracture it is earthy, and always colored, while, instead of a transparent glaze, it is coated with enamel.

In the composition of the mass, certain proportions of potter's and plastic clay, clay marl, and quartz or sand, will always be found—these constituents varying in their nature according to the different localities in which they occur. Thus Paris earthenware consists of—

Plastic clay from Arcueil,	8
Greenish clay marl,	36
White calcareous marl,	28
Yellowish marly sand,	28
	100

Still the various combinations always contain a mean proportion of clay, silica, and carbonate of lime, as will be seen by the following analyses of earthenwares from various localities:—

Description of earthenware.	Silica.	Alumina.	Lime.	Magnesia.	Oxide of Iron.	Carbonic acid and loss.	Remarks.
Italian, from Lucca della Robbia,	49.65	15.50	22.40	0.17	3.70	8.58	All effervesce with acids.
Majolica,	48.00	17.50	20.12	1.17	3.75	9.46	
Old Spanish,	46.04	18.45	17.64	0.87	3.04	13.96	
Manasses, near Valencia,	54.71	18.80	19.69	trace	2.20	4.60	
Delft,	49.07	16.19	18.01	0.82	2.82	13.09	
Persian,	48.54	12.05	19.25	0.30	3.14	16.72	
From Rouen,	47.96	15.02	20.24	0.44	4.07	12.27	
From Nevers,	56.49	19.22	14.96	0.71	2.12	6.50	
From Paris,	61.50	12.99	16.24	0.15	3.01	6.10	

The mean of these proportions corresponds nearly with equal parts of silica, pipe-clay, and carbonate of lime. These analyses likewise show that the greater portion of the carbonate of lime has been decomposed by the silica during firing, the amount of carbonic acid contained in the vessels being far too small a quantity to combine with the whole of the lime. All kinds of delftware melt and swell at a high temperature into the form of a dark-brown or green glass, without becoming translucent. The liability to crack, when exposed to sudden variations of temperature, is likewise increased by the large amount of marl in the mass. A corresponding increase of pure clay diminishes the risk.

All the ingredients for delftware are suspended in water, and mixed in the slip state; the mass being brought to the proper degree of consistency for working by evaporation in slip kilns. The operation of forming or moulding upon the throwing-wheel is one of extreme rapidity from the great plasticity of the mass; the finishing processes being afterwards performed upon the lathe. Sometimes plaster moulds are employed; but, in every case, the processes are the same as those already described.

Firing.—Delft earthenware, like fine earthenware, is fired twice; the first baking producing the *biscuit*, which, after receiving the glaze, is fired the second time. Both these operations are carried on in similar kinds of kilns, which are generally upright reverberatory furnaces heated by one or more fire-places, after the manner of those already described. In the firing, the wares of better quality are protected from the flame by inclosure in seggars, while the commoner kinds receive

support in the kiln by clay slabs specially prepared for this purpose, and arranged in separate layers or floors, between which the wares are placed so as to afford free circulation to the flame. The pieces are separated from each other in the seggars by triangles and pegs, as already described. The first firing lasts from fifteen to sixteen hours, and the second for burning on the glaze from twelve to fourteen hours.

The temperature of the kiln averages about 27° Wedgwood. The mass shrinks in the baking from ten to twelve, fourteen, or even fifteen per cent. according to its composition.

The analysis of common delft earthenware is as follows:—

Alumina and sesquioxide of iron,	68.55
Silica,	29.13
Lime,	1.24
	98.82
Specific gravity,	2.363

The glaze or enamel is composed of quartz-sand, soda, common salt, and a mixture of calcined tin and lead. The two metals are more easily oxidized when mixed; the oxide of tin produced— Sn O_2 —acting the part of an acid to the oxide of lead— PbO . The mixture is prepared by placing the lead with about one-fourth of tin in a special furnace, where it is exposed to heat and a current of air. A yellowish ash of tin and lead is formed, which is carefully calcined to oxidize thoroughly all the metallic particles. This metallic ash is mixed to form the enamel in the following proportions:—

No. 1.		All sand for opaque glazes should be fritted with soda as follows:—150 sand to 100 soda.
Lead and tin ash, ..	100 parts.	
Sand,	100 parts.	
Salt,	15 parts.	
Red lead,	5 parts.	
No. 2.		Fritted together, with the addition afterwards of 50 pounds of white lead.
Lead and tin ash, ..	32 parts.	
Soda,	9 parts.	
Salt,	5 parts.	
Cornish stone,	25 parts.	
No. 3.		Fritted together, with the addition afterwards of 100 pounds of white lead.
Calcined sand,	100 lbs.	
Soda,	50 lbs.	
Tin ashes,	25 lbs.	
No. 4.		
Best earthenware glaze,	10 quarts.	
Oxide of tin,	40 oz.	
White lead,	60 oz.	

The larger the proportions of tin in the ash the harder the enamel produced, and *vice versa*. The frit, ground and mixed with water, is applied to the wares in the usual way.

Majolica ware—the revival of which in this country is due to Messrs. MINTON, under the direction of M. ARNOUX. The body consists of a soft calcareous clay, or common delftware body, gently fired and covered with an opaque enamel composed of sand, lead, and tin, forming an excellent surface, upon which the decorations in color are afterwards painted by hand in the various preparations and fired into the glaze. Very elegant cisterns, vases, flower stands, *et cetera*, are now produced in this ware; it is also applicable for the production of friezes and other architectural ornaments. It likewise affords a cheap material for enamel painting, the brightness of tints attained being equal to that produced upon copper. The mode of production may be thus described:—The ware, after formation in the usual manner, is twice fired, first for the biscuit, and afterwards to receive the enamel or basis for receiving the color. In this state it is taken to the decorator, who with his brush paints on the several pigments prepared for the purpose, the ground color being only laid upon such portions as are to be covered, and the several ornamentations added in the same way, each only receiving its particular tint. Great care and nicety are required in this manipulation to prevent the unequal blending of the colors at the edges. Sometimes a shaded effect is given to the ground or ornamentation by the running of the colors into the hollows of the pattern, causing in the firing a greater depth of tone. At other times color is laid over the first ground, and a pleasing blended effect is produced by the running together of the enamels in firing. After the decoration is completed in this manner, the piece is taken to the *muffle*, where the colors are all burnt or fired into the glaze, giving that rich solidity of tone and lustre so peculiar to majolica ware. The proportions for the enamel are here given:—

ENAMEL GLAZING FOR MAJOLICA WARE.

No. 1.	
Lead,	77
Tin,	23
Calcine together, and take—	

Calcine,	44 parts.
Sand,	44 parts.
Red lead,	2 parts.
Salt,	8 parts.
Soda,	8 parts.

No. 2.

Lead,	82
Tin,	18

Calcine, and take—

Calcine,	47 parts.
Sand,	47 parts.
Salt,	3 parts.
Soda,	3 parts.

No. 3.

Lead,	77
Tin,	23

Calcine together, and take—

Calcine,	45 parts.
Sand,	45 parts.
Red lead,	2 parts.
Salt,	5 parts.
Soda,	3 parts.

No. 4.

Lead,	82
Tin,	18

Calcine together, and take—

Calcine,	45 parts.
Sand,	45 parts.
Salt,	7 parts.
Soda,	3 parts.

All these compounds are fused together, and sometimes yield a blackish mass; but when ground and applied to the wares, they appear as a white enamel glazing.

The following are the colors applied to them:—

Yellow.

White enamel glazing,	91 parts.
Oxide of antimony,	9 parts.

Blue.

White enamel glazing,	95 parts.
Cobalt calx,	5 parts.

Green.

White enamel glazing,	95 parts.
Oxide of copper,	5 parts.

Yellow Green.

White enamel glazing,	94 parts.
Oxide of copper,	4 parts.
Naples yellow,	2 parts.

Violet.

White enamel glazing,	96 parts.
Peroxide of manganese,	4 parts.

Other colors are merely modifications of these, with other compounds.

The white glazing of some of the modern majolica is composed of felspar, borax, and the oxide of tin. This glazing, as well as the colors, is frequently applied directly to the biscuit ware, which considerably reduces the labor of ornamentation, without detracting from the beauty of the manufacture.

ORDINARY POTTERY, such as is now everywhere produced, is intended to afford the less wealthy classes cheap utensils, that are *impervious to liquids*, and which at the same time will *bear changes of temperature*, so as to admit of general domestic use. Ordinary pottery is made in almost every locality, and therefore, of necessity, from very different kinds of clay. Its

extreme cheapness obliges the use of those clays that can be obtained at least expense, such as potter's clay, marl, *et cetera*, and the application of the most ordinary methods of moulding and firing. From the circumstance that ordinary pottery is generally manufactured by a class of persons without the means and opportunities of introducing improvements, the advance of the manufacture is slow; the waste of fuel in badly constructed kilns is frequently a source of great loss, while many of the clays worked into the mass will not withstand a sufficiently high temperature. Ordinary pottery is, therefore, always fired at a comparatively low heat, which renders the mass porous and of low density, and necessitates the use of a glaze. As the temperature required to burn on this glaze must be lower than that which would cause the fusion of the ware, it is generally a lead glaze, and of a very fusible nature. This glaze is always transparent, no attempt being made to conceal the body of the ware, which is generally of a dirty-red, yellowish-brown, or greyish color. The glaze may either be colored or not, the rude paintings with which ordinary potters' ware is sometimes decorated being produced by glazes of different colors, the one forming the ground and the other the ornamentation. In general, a very low style of art pervades the tone of this class of clay wares, though occasionally exceptions are met with, such as the wares produced at Marburg, where the brown colored vessels are neatly ornamented with floral designs, that appear to advantage through the light yellow glaze.

In the preparation of the mass two operations only are required—one, the mixing the clay with the necessary amount of water to bring it to the proper consistency, and during which operation the clay is frequently stirred and turned over to render the action of the water uniform; the other, after evaporation, is the working the mass into lumps, and the removal of all knots, stones, *et cetera*, by the aid of the wire, as already described under *Earthenware*. Clay, when of good quality, is easily worked upon the throwing wheel, and does not shrink so much in the kiln as to cause cracks, besides possessing the qualification of carrying the glaze. These properties, which cannot be previously determined, are all matters of experience, different clays being frequently mixed together for that object, with the addition of sand to diminish contraction when the clay is too fat.

The glaze in use upon ordinary potters' ware is an aluminous lead glass prepared from litharge or galena, which in the firing forms oxide of lead and lead salts, the former combining with the silica.

The substances containing the lead are finely ground and mixed in proper proportions with loam, or if a transparent colorless glaze, with sand. When color is required, metallic oxides are used as pigments—oxide of copper for *green*; manganese for *brown* and *black*; zaffre for *blue*; red antimony ore for *yellow*; and iron for *red*, *et cetera*.

The glaze is generally applied to the surface of the ware either by coating or sprinkling the moist vessels with the glaze powder, the operation of dipping being in general too expensive for this kind of ware.

The proportions between the oxide of lead and silica in the glaze are very variable, sufficient time being generally allowed in the furnace for the oxide of lead to become fully saturated with silica. That this is the case when the heat of the furnace has been sufficiently intense, is demonstrated by the following results of experiments made on twelve vessels specially marked, and after firing digested for some time in distilled vinegar—

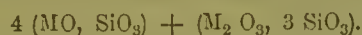
Those *too hard fired* gave no indications of lead.
Those *hard fired* gave no indications of lead.
Those *well fired* gave in some cases only traces of lead.
Those *ill fired* gave in every case indications of lead.

In badly baked ware, therefore, acid liquids upon the first application dissolve the oxide of lead which is uncombined, or only in weak combination. The amount of lead so dissolved, however, is very small, and the application of lead glaze to the wares is not attended with any danger to the consumer, notwithstanding the great outcry that was raised against its use as engendering endemical diseases.

Often glazes free from lead are used, especially in Vienna, where the glaze contains—borax, one hundred pounds; felspar, fifty pounds; loam, fifty pounds. In Bavaria the glaze consists of the slag from the smelting furnaces, a transparent mass harder than glass, and which gives sparks when struck with steel; in color it is either bottle-green or light and dark blue passing into green; it is not acted upon by acids. In the analyses made by REINSCH it was found to consist of—

		Oxygen.	
Silica,.....	65.00	33.70	in the silica.
Lime,	12.35	3.53	
Magnesia,	2.56	0.99	7.37 in the bases
Potassa,.....	2.00	0.34	MO.
Protoxide of iron,.....	5.00	1.50	
Alumina,	8.00	3.73	5.06 in the bases
Oxide of manganese,...	4.45	1.33	M ₂ O ₃ .
	99.36		

Corresponding very closely with the formula—



Although not identical with bottle glass, it is nearly allied to it. This slag is ground up with water, and applied by pouring it over the ware, previously coated on the outside by immersion with a thin film of loam, to give the red-brown tint. The high temperature required for the fusing of this slag, is one of the chief objections attending its use and general introduction as a glaze.

The *kilns* in which ordinary potters' wares are fired are long, horizontal, reverberatory furnaces with one fire-place, from which the flames traverse the introduction of the ware, the smaller pieces in lengthwise towards the chimney situated at the opposite end, and in which is the aperture for charging the kiln being placed inside those of larger dimensions. As the temperature of the kiln diminishes rapidly towards the chimney, a proper disposition of the wares is necessary, those coated with the more fusible lead glaze being placed where the temperature is lowest. The wares are all exposed to the direct action of the flames, precaution being taken to prevent their adhesion together

in the fusion of the glaze. Further description or illustration of the ordinary potter's kiln is here unnecessary, the wares being frequently fired in the same kilns with stoneware and bricks, an account of which will be found under the article *Tiles*.

The application of glaze to common potters' ware is sometimes omitted, as in the case of articles for which rapid absorption or evaporation is necessary, such as water coolers, sugar-moulds, butter-dishes, flower-pots, *et cetera*.

The cooling bottles and vessels used for holding liquids illustrate well the use that is made of the porous nature of unglazed clay. Their cooling properties arise from the permeation of the liquid through the pores of the ware to the exterior surface where, by exposure to the air, it is evaporated with great rapidity, maintaining the interior liquid at a temperature several degrees below that of the surrounding atmosphere. The porosity is sometimes increased by the admixture into the mass of substances which will be destroyed in the kiln, leaving minute pores through the body of the ware; a similar effect is produced by a low temperature of the kiln during firing.

Lustre ware is a class of common pottery which receives upon the glaze, after firing, a very thin, delicate, and brilliant coating of metal, burnt in by a subsequent process in a muffle. The reduction of the metal is effected either by some ingredient in the solution, or by a reducing atmosphere through the action of heat. Sometimes the lustre imparts color to the glaze, as well as the metallic coating, an effect of the extreme tenuity of the coating and partial oxidation of the metal.

This effect is produced in a remarkable manner by the *gold lustre*, which is obtained by precipitating a solution of gold in aqua-regia by means of ammonia, the precipitate, which is fulminating gold, being mixed while moist with essential oil of turpentine. In this state it is applied to the surface of the ware, and fired in the muffle, the lustre being brought out afterwards by friction with linen.

Another preparation for the gold lustre is as follows:—Two pennyweights of gold, dissolved in twenty-five drachms of aqua-regia, with about sixty drops of the solution of tin; the solution being gradually added to six ounces of balsam of sulphur, into which a pint of spirits of turpentine is slowly added, constantly stirring until the whole mass is smooth.

Platinum Steel Lustre is formed from a solution of bichloride of platinum in ammonia, mixed by means of a glass rod with *spirit of tar*, composed of equal parts tar and sulphur, boiled in linseed oil, and filtered. The mixture is spread upon the piece, and fired in the muffle, great attention being paid to the temperature of the kiln. If the platinum solution is too strong, it is reduced by the addition of more spirits of tar, and if too weak, concentrated by evaporation. If the wares come out black from the kiln, friction with cotton restores the proper color.

Silver Lustre, which has a silver white hue, is also obtained from platinum, dissolved in equal parts of muriatic and nitric acid; the saturated solution is poured into boiling water, and a yellow precipitate of

the metal is obtained by pouring this mixture into a warm solution of sal ammoniac, which, after being washed with water and dried, is applied in the usual way to the surface of the ware by means of a fine camel-hair pencil; it is then fired, not beyond a red heat, and afterwards burnished with a piece of soft leather.

Lustre Cantharide—the remarkable iridescence of which resembles beetles' wings or Spanish flies—is produced from glass containing a large quantity of lead, and to which is added oxide of bismuth and chloride of silver. The wares after coating with the preparation are placed in the muffle, and when heated to redness, leather or similar substances thrown in, the products from which reduce the surface of the metal and produce brilliant coatings, varying in color from green, red, yellow, blue, *et cetera*.

Iron Lustre is obtained by dissolving iron or steel in muriatic acid, and mixing the solution with spirits of tar. The following may be given for the mixture forming the body of lustre ware:—

MASS FOR LUSTRE BODIES.

I.

Red or brown clay,	20 parts.
Cornish clay,	8 parts.
Blue clay,	4 parts.
Flint,	2 parts.

II.

Red clay,	50 parts.
Earthenware body,	7½ parts.
Manganese,	1 part.
Flint,	1 part.

III.

Red clay,	80 parts.
Black Egyptian,	10 parts.

The lead glaze for lustrous ware is usually made as follows:—

Litharge,	60
Felspar,	36
Flint,	15

or other good cream colored glazes.

TILES AND BRICKS.—In considering the formation of the mass, and the subsequent operations by which it is made to assume the required shape, and the degree of hardness desired in this description of clay wares, a similar arrangement and classification will be adopted to that given under **POTTERY**, properly so called.

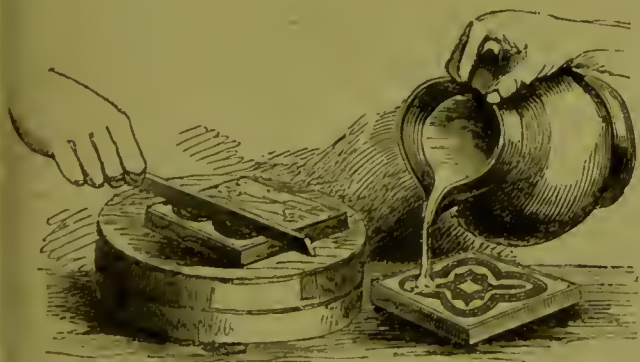
Mosaic, Plain, and Encaustic Tiles, from the superior density and vitreous fracture of the mass, together with the presence at times of a glaze, and the amount of skill and taste displayed in their design, are justly entitled to take precedence in this department of manufacture.

Mosaic Pavements and Inlaid Paving-tiles.—The manufacture of the highly decorative pavements of the medieval period has, after the lapse of ages, been revived in the art manufactures of this country by the untiring zeal and industry of the late Mr. HERBERT MINTON, under the direction of Mr. M. D. HOLLINS. The chief difficulty in the production of this manufacture is to obtain different colored clays that shall contract and shrink equally during the processes of drying and firing, and without which property it would

be impossible to produce a perfect tile of variegated colors. It is unnecessary to speak of the state of perfection to which these beautiful tiles are now brought, or their fitness for architectural and ecclesiastical decoration. The fine stone body of which they are composed being highly vitreous, and capable of receiving almost any shade of color, renders them peculiarly adapted for such a purpose. The manufacture is extensively carried on by the Messrs. MINTON. The red clay, composing the body of the encaustic tile, is found at Cobshurst, about four miles from Stoke-upon-Trent, and in manipulation receives a facing of a finer clay, to bear the ornamental or colored design, while the back of the tile has a similar layer pierced with holes, the object of which is to prevent the warping of the tile in the fire. The fine clay, composing the ornamental portion of the tile, contracting more in the kiln than the body, would cause it to bend, unless this tendency were counteracted by the layer of similar material placed at the back. The red clay, or marl, previous to working up, is allowed to *weather* by exposure to the air for about half a year. It is then thrown into the mixing vats, as required, and blunged up well with water; after which the clay slip is strained from all impurities by passing it through fine lawn sieves, and evaporated in the slip kiln to the proper consistency for working; or the mass, if for *dry tiles*, is dried into hard lumps, and afterwards ground between mill stones into fine powder, according to the particular processes for which it is intended.

The clay for the body of the encaustic tiles, after wedging and slapping in the usual manner, is shaped into a block in the form of a cube, or parallelepiped, from which the tilemaker cuts off with a wire square slabs nearly approaching in thickness that of the intended tile. These small slabs now each receive the colored facing of finer clay, which is battled out

Fig. 484nn.



and slapped down on their surface. Each tile thus formed is covered with a piece of felt and put into an iron box press of the required size, where it receives pressure upon a plaster of Paris mould having the pattern cut in relief upon its surface. The soft colored clay face thus receives the design, the indentations of which are afterwards filled up with various colored clays. The name of the maker and a few holes to cause adherence to the cement when fixing the tile and also to assist in withdrawing the moisture in the

drying process, are then stamped upon the back, and it is allowed to harden slightly before the next process of filling takes place. The colored materials in the form of thick slip are now poured over the various parts of the indented pattern so as to completely cover the surface—Fig. 484nn. In about twenty-four hours this colored slip is sufficiently hardened to allow of the superfluous clay being removed; for this purpose the tile is placed upon a small whirler, and the pattern brought out by scraping away the clay down to the face of the tile, the cavities only being filled with the colored mixtures. The tile is now properly finished, the edges squared, and all defects corrected; after which it is dried for a week in a warm room before being removed to the stove where the drying process is completed in a period, occupying from fourteen to twenty-one days, according to circumstances. When thoroughly dry the tiles are packed in seggars and fired in the manner described under *Earthenware*, the duration of the baking averaging about sixty hours. The oven is left to cool for six days, after which the tiles are withdrawn in their finished state. The mass contracts in the firing to the extent of one-eighth in every inch. To produce, therefore, an ordinary six-inch square tile, it is necessary to form the model six inches and five-eighths to allow for this shrinkage.

For the formation of encaustic tiles of a more elaborate pattern, the process is varied from that described, the tile being moulded by hand, instead of receiving pressure under a machine; and it is by this manipulation that all the rich and expensive pavements have been produced. These pavements have been introduced in Osborne House, the residence of her Majesty; and under Sir CHARLES BARRY's direction in the House of Lords and the House of Commons; Cleveland, near Maidenhead, the residence of the Duke of Sutherland; and the mansions of most of the nobility, as well as the Senate House, Washington, and St. George's Hall, Liverpool.

Plain self-colored tiles, such as black, red, chocolate, buff, *et cetera*, and also the *tesserae*, are generally termed *dry tiles*, and made of similar material to the encaustic tiles, but subjected to an entirely different process under a method patented by Mr. PROSSER. The prepared clay, after drying upon the kiln till it is quite hard, is ground between stones and reduced to a fine powder, which is afterwards placed upon gypsum slabs slightly damped, and sifted through fine sieves. In this state the quantity required is placed in a strong steel matrix or mould of the size of the intended tile, the bottom surface of the matrix being ribbed, to give a corresponding impression to the bottom of the tile, and cause its adherence more firmly to the mortar or cement in which it may be afterwards embedded, as well as to distinguish the size of tile by the different diapering. Into this matrix, a steel plate with the pattern of the intended tile upon its surface accurately fits, and is brought down with immense pressure upon the surface of the powdered clay, the pressure applied being so great, that the particles are united into a firm solid slab or tile ready for drying and firing. A thickness of three inches of powder will by this compression form a tile one inch thick, sharp in outline, and with a beautiful

polished surface. It is also found that compressed tiles shrink less in the firing than those made from the plastic mass, the former contracting only one-sixteenth in every inch. Many other articles are likewise manufactured by this compressing process, such as scale plates, table tops, furniture panels, *et cetera*, and also with smaller presses and dies, the tesserae for mosaic work, and ornamental buttons for shirt studs.

The number of tiles produced by a single machine is very large, between fifty and sixty dozen being often turned out in ten hours by the labor of one man, while the number of tesserae produced in the same time is scarcely less than from twenty to twenty-five gross.

The celebrated white-glazed tiles which are now so much appreciated for the walls of bath-rooms, dairies, and other domestic comforts, are largely manufactured by this firm under the same process.

Many other descriptions of vitreous paving tiles are also made, and are in large demand for the more ordinary purposes of architectural embellishment. At Tuustall, near Burslem, at the Tilery Works of Messrs. GARRETT Brothers, great improvements have been effected in the form and appliances into which this material can be worked. Hollow pillar shafting of red clay for churches, ventilating ridge roof tiles, and various other applications might be mentioned, as showing the immense field of constructive art into which this material, under skillful treatment, may be carried. In general, the manufacture of tiles being very similar to that of *bricks*, many of the operations will be described under that section.

Tiles may be classed under three divisions, paving tiles, roofing tiles, and drain tiles, each of which comprehend numerous other varieties. The great distinction between tiles and bricks arises from the greater thinness of the former, and the consequent necessity of increased purity and tenacity in the mass; greater care is also bestowed upon the processes of their manufacture, tiles being always dried under cover.

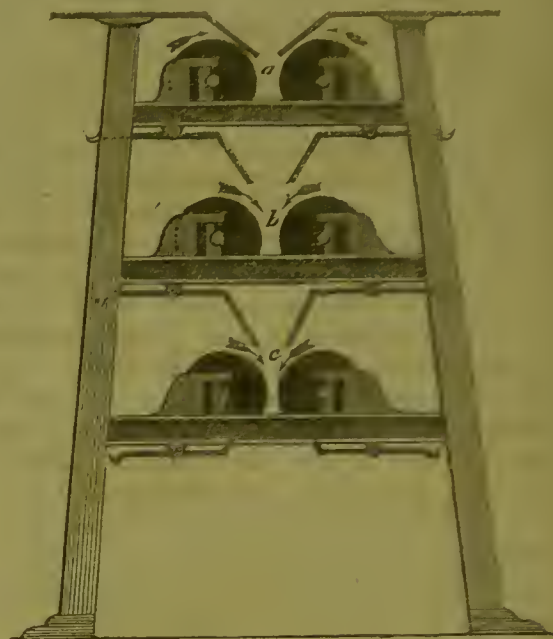
Roofing Tiles are of three kinds—pan tiles, which are of a curved shape; plain tiles, flat and of various shapes, often arranged to form elegant patterns when laid upon the roof; and ridge roof tiles, formed to cope the top of the roof, and often highly ornamental.

Drain Tiles belong to the coarsest class of earthenware, and are of various shapes; sometimes curved over a mould, and sometimes formed by forcing the material through a machine by mechanical means. Other articles, likewise, come under this denomination of wares in their manufacture, such as chimney-pots, tubular pipes for water or drains, and which sometimes require the assistance of the lathe to complete their formation.

Processes of Manufacture.—The marls used to form the mass for working are previously weathered and tempered, the period of exposure depending upon the state of the weather; a frosty atmosphere or a warm sun is more conducive to speedy tempering than a succession of wet and dry days. The marls, when in a proper condition, are taken to the crushing mill—Fig. 48400—where, by passing successively between the sets of rollers, *a, b, c*, through a gradually narrowing aperture, the mass becomes thoroughly pulverized, and

in this state is thrown into layers of the various marls, where it is again weathered, and left for a considerable time to mellow or ripen, and sometimes water is added to hasten this process. It is afterwards tempered and

Fig. 48400.

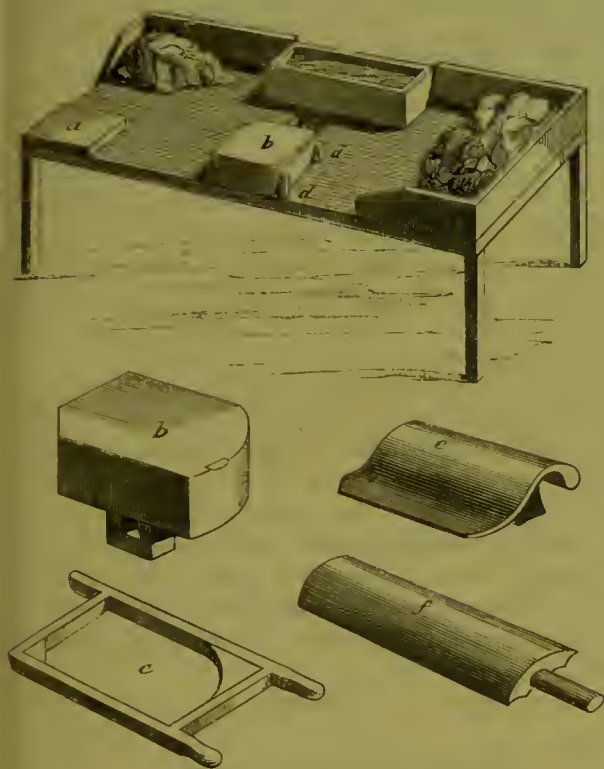


prepared for the moulding processes by passing through the pug mill—see *Earthenware*—from whence it comes oozing out in a mass thoroughly kneaded together and possessing great tenacity. This plastic mass, after separation into blocks or lumps, is conveyed away and stored under cover for future use.

The *moulding* or forming of pantiles is carried on under sheds, the moulding tables being placed on one side, while the remaining space is filled with the *blocks* or drying shelves to receive the pantiles after forming. The prepared clay, after being cut into lumps termed *half pieces*, is brought to the moulding table—Fig. 48400—where the lumps are batted and squared up by an assistant into masses or slabs, *a*, about the size of the mould, and about four inches thick. From this block, by means of a wire, he separates a thin slice the size of a tile, and passes it over to the moulder. The *block* and *stock board*, *b*, for receiving the tile-mould is firmly secured to the moulding table by a strong tenon and mortice; four pegs, *d*, driven into the table at the corners of the block and stock, serve as a support to the mould, *c*, and at the same time regulate the thickness of the tile—five-eighths of an inch. The moulder, having sanded his stock-board and placed his mould on the four pegs, takes the slice of clay from the assistant, and placing it in the mould, smooths the surface with wet hands, and with a brass wire strained upon a wooden bow cuts off the surplus clay level with the mould, and turns the tile out upon the *washing-off frame*, *e*, where it is pressed by the hand into the requisite curved form. It is now struck smartly with the splayer, *f*, and turned over upon that implement for conveyance to the block, where, on withdrawal of the splayer, it is deposited for drying with the convex side uppermost, remaining here for

one or two days. When the tiles are nearly dry they are taken to the *thwacking-frame* or horse, the top of which is curved to correspond with the intended outline

Fig. 484pp.



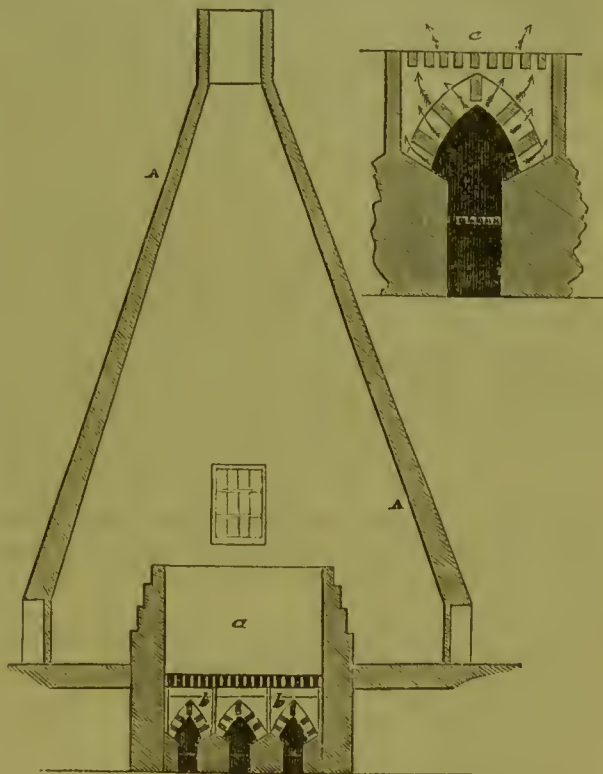
of the tile, and fitted with a wooden block similarly curved. Six or seven of the tiles are now placed upon this horse, and the workman lifts up the wooden block and gives them two or three smart blows, which corrects any warping that may have taken place during the drying process. The tiles are now carried to the kiln.

Firing.—The tile kiln—Fig. 484qq—as constructed in the neighborhood of London, consists of an oven or chamber, *a*, heated underneath by furnaces, *b*, from which the flames circulate freely through the oven by the flues shown in detail at *c*; the whole is inclosed in the brick hovel, $\Delta \Delta$. The time occupies six days, the fires being lighted on Monday morning, and not put out until Saturday evening. The consumption of coal for each firing is about eight tons, but varies with the nature of the goods to be burnt; hollow goods, such as chimney-pots, garden-pots, *et cetera*, requiring less than the more solid wares. These kilns average seventy-five feet in height to the top of the hovel, with an interior diameter of about thirty-six feet; the oven itself being about fourteen feet square by ten feet high.

In the Staffordshire potteries the kiln is of more moderate dimensions; and the fires not being placed in vaults underneath the body of the kiln, are in general protected from the set of the wind by a wall about six feet high surrounding the kiln, and placed at a convenient distance to allow space for the proper regulation of the fires. After the oven is filled, the doorways are built up with bricks daubed over with street-sweepings or clay as a luting; and the fires, after kindling, are burned slowly for the first five hours, after

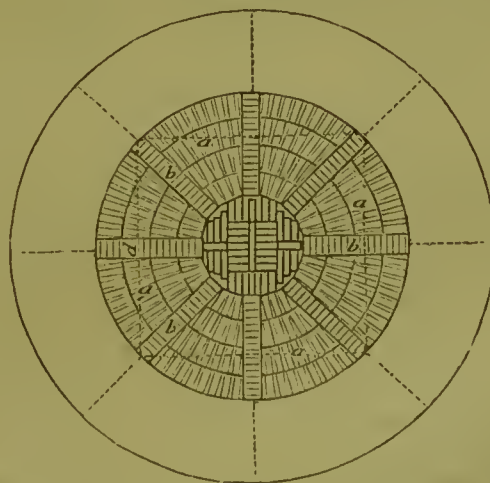
which the heat is progressively increased for the next thirty-three hours; the space of thirty-eight hours being in general sufficient for hard fired blue tiles or bricks.

Fig. 484qq.



The temperature of the kiln is determined by the appearance of the mouths and top outlet of the kiln, as well as by trial pieces. When sufficient heat is attained, and before the fires burn hollow, the mouths are banked up with ashes to prevent the passage of cold air through the oven; and the whole is allowed

Fig. 484rr.



to cool gradually for twenty-four hours before the contents are removed. The operation of firing the kiln generally takes place once a week, and consumes from five to six tons of coal and slack. In charging the oven, the floor is first laid with about two thousand bricks placed edgewise in courses one above the other, *a*—Fig. 484rr—the bricks in the first seven courses being so

disposed as to leave a flue from each fire-place of an average width of seven inches, and the top course, *b*, so as to cover this space, and form the flues. Upon this foundation the tiles are placed in bungs of twelve laid alternately cross and lengthwise; the nibs on the tiles spacing them off, and supporting them in a vertical position. Each side of the square is built up with bricks, *d*, allowing sufficient space in the interstices for

the uniform diffusion of heat through all the goods placed in the oven, a desideratum of the greatest importance in the firing of blue bricks and tiles, and for which the circular form of oven is found best adapted.

The following table gives the analyses of the clays used in the Staffordshire potteries, and found in the district, arranged in the order of their *fusibility*, commencing with the most easily-fusible clay:—

ANALYSES OF CLAYS FROM BASFORD AND THE STAFFORDSHIRE POTTERIES.

	1.	2.	3.	4.	5.	6.	7.	8.
Silicic acid,.....	42.84	54.38	59.44	60.02	64.32	65.78	69.87	70.17
Alumina,.....	17.61	26.55	25.93	24.26	20.33	15.16	16.79	16.25
Sesquioxide of iron, and a little protoxide,	6.97	—	10.74	9.14	10.86	8.49	8.88	8.41
Protoxide of iron, and a little peroxide,..	—	8.38	—	—	—	—	—	—
Lime,.....	15.36	—	—	1.60	trace	1.67	trace	1.29
Carbonic acid,.....	11.61	3.14	—	—	—	—	—	—
Oxide of manganese,.....	2.20	—	trace	trace	—	—	—	—
Soda, and a little potassa,.....	—	—	—	1.40	—	—	—	—
Water,.....	3.94	7.28	3.11	3.89	6.60	5.37	4.26	5.86
	100.53	99.73	99.22	100.31	102.11	96.47	99.80	101.98

The colors to which the different clays burn in the kiln are given below, the figures corresponding with those of the above table:—

1. Rotten red marl will not stand heat, but fuses.
2. Seggar marl burns *light buff*—a firebrick.
3. Mixture of clays 5, 6, 7, 8, burns *good blue*.
4. Clay from Stoke-upon-Trent burns *red*.
5. Dun-colored marl burns *good blue*.
6. Top-yellow marl burns *reddish blue*.
7. Red marl burns *blue*.
8. Mingled marl burns *blue of a reddish tinge*.

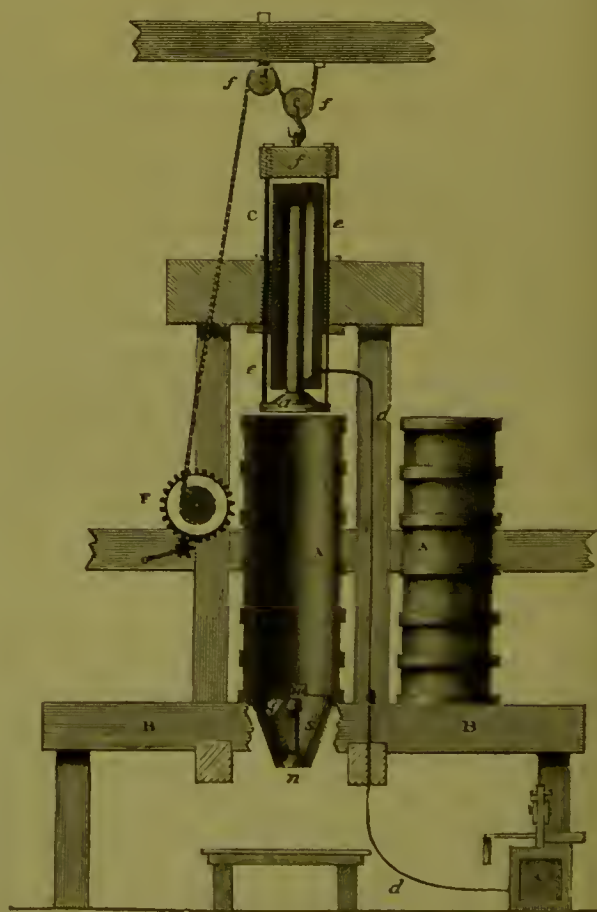
Ornamental ridge and roofing tiles are in general made by a similar process to that described, greater care being required in the moulding and formation of the piece according to the nature of the design; and if this be very elaborate, the tile is sometimes formed of separate pieces united together after moulding, much in the same manner as described under *Earthenware*.

Of late years considerable ingenuity has been exercised in the invention of machines to supersede hand labor in the production of roofing, agricultural drain tiles, water pipes, *et cetera*, all which machines are constructed upon the principle of forcing the prepared clay from a cylinder through a die-plate fixed at one extremity, which delivers the tiles or tubes in the various forms required. As similar machines for the production of bricks will be noticed under that head, it will be sufficient here to describe the method of producing drain pipes by the hydraulic press, carried on at the manufactory of REICHENECKER, at Ollweiler in Alsace; a process which will at once explain all others of a similar character. The clay mixture to form the pipes, after proper purification, is thoroughly kneaded by passing it between two cylinders revolving at different velocities, which causes them to exert a tearing action upon the mass, the distance between the cylinders being regulated by serews. The mass undergoes a further process, which is necessary before it passes to the moulding apparatus, namely, the expulsion of the minute particles of water retained in the clay by the force of capillary attraction, so powerfully as to resist the action of the press, and which would prevent the

mass from attaining that degree of density necessary to insure its durability and nonabsorbing quality when exposed to constant pressure and the action of liquids.

It is desirable that the mass shall not become too dry, otherwise the process of moulding would be

Fig. 484ss.



rendered difficult; a medium is therefore secured by breaking it up into balls of about eight inches dia-

meter, which are suffered to half dry, and are afterwards repeatedly *slapped* upon a smooth stone to produce a perfectly homogeneous mass. The moulding press—Fig. 481ss—consists of two hollow cast-iron cylinders, A A, fixed near each other on a strong movable frame or cradle, B B, by which means they can be brought alternately under the ram, *a*, of the powerful hydraulic press, C, and which is brought into action by the pump, *c*, and supply pipe, *d*. The rods, *ee*, which are attached to the descending beam, *f*, are for the purpose of raising the ram after each operation, the winch, F, and pullies, *ff*, carrying the rope. The conical moulds, *m*, with the mouthpiece, *n*, for the pipes, are attached to the lower extremities of the cylinders, A, and are changed according to the nature of the article to be manufactured. These conical moulds carry the cast-iron mouthpiece, *n*, by the rod, *s*, passing through the centre, and secured into the crosspiece, *g*, cast in one piece with the mould. The plastic mass placed in the cylinder is thus forced by the pressure of the ram through the mouthpiece into the shape of a tube or other article, and is cut by a wire into the requisite lengths, which are removed on a tray to the drying kiln, where they are placed in an upright position upon perforated supports, to avoid as much as possible any bending or want of uniformity in the drying process, a circumstance which would infallibly cause them to split in the kiln. The operation of firing is always one of great risk, as, notwithstanding the care that is taken, the pipes often crack in a longitudinal direction. The application of hydraulic power to the formation of these pipes renders them sufficiently dense and strong to resist a pressure of from thirty-five to forty atmospheres—over one thousand pounds to the square inch—an amount far beyond the capabilities of a pipe manufactured in the ordinary manner. Their diameter varies from one inch to about eight inches, with a proportionate increase in the thickness of the substance. Pipes of a somewhat similar nature, but of larger dimensions, are manufactured by GARRETT Brothers, near Burslem Peake, and others in the locality, at Llwynnion, North Wales, and also at Lambeth, London.

Bricks or artificial stones are intended to replace natural stone whenever this is not to be had, or the hewing and cutting becomes too expensive. Bricks, therefore, are always formed or moulded at once into the required form, varied according to the purposes for which they are intended, such as wall bricks, arch and rectangular or wedge-shaped bricks. These forms never exceed more than a few inches in thickness, on account of the contraction and difficulties attending the drying of larger masses, and they acquire the requisite solidity by burning in the kiln. From the necessary competition into which artificial bricks enter with natural stone, economy in production is an essential point; they are therefore seldom ornamented, and the color is generally confined to the natural hue assumed by the clay in firing. The preparation and purification of the mass are also extremely simple, and are generally performed upon the *field* where the materials are obtained. Bricks, being thicker and more massive than ordinary potters' ware, are necessarily subject to a much greater contraction, and consequent

liability to crack—a defect which is remedied as much as possible by mixing into the mass cheap noncontractile substances, such as sand, calcareous marl, coal and coke refuse, peat, sawdust, *et cetera*. Sometimes the brick earth contains naturally a sufficient amount of sand or lime, at others the mean quality is obtained by a mixture of clays.

In the neighborhood of London, where bricks are the only material employed for building, the clay is obtained from the alluvial deposits in the London basin that lie above the *London clay*, and consists of layers differing in composition from each other. The lowest deposit containing clay, mixed with fragments of chalk and various gravels, *et cetera*, is rarely used, and passes gradually into the middle stratum termed *malm*, also of clay, but mixed with finer fragments of chalk and sand, in place of the coarse gravel; while in the upper layer the clay preponderates, the gravel and sand being in much smaller quantities, and the proportion of lime is so small that the clay hardly effervesces with acid. This upper stratum is there too fat, and requires to be incorporated with coal cinders or sand, while the middle strata possessing more sand receive only the addition of cinders. Near London and other large towns in England the bricks of the greater number of houses are composed of the earth removed from their foundations. From the uses to which bricks are applied, it is essential that they fulfil certain conditions, as follows:—

Bricks, to be good, must be sufficiently firm and hard to support, without crumbling or giving way, the superincumbent mass they have to sustain, and not be subject to break in carriage.

Bricks must be made so as to withstand pressure, to lie flat upon one another, and have a smooth straight surface free from hollows and cracks.

They must also possess sufficient porosity to admit of a proper degree of adhesion to the mortar, and cause it when dry to form a firm and durable cement.

They must, likewise, possess a hard and uniform structure throughout, so as to afford facility in dressing with the trowel, and not split in contrary directions. They should be able at the same time to withstand changes in temperature, when placed in flues, fire-places, chimneys, *et cetera*, as well as the influences of moisture and frost from external causes.

Some of these necessary qualifications can only be attained by a proper mixture of the mass, and others by attention to the processes of moulding and firing. These varieties of clay are generally incorporated with various substances, such as lime, iron, pyrites, stones, gravel, organic remains, *et cetera*, which, unless removed, are very injurious. Thus when clay containing particles of limestone, chalk, or calcareous petrifications, is formed into bricks, the firing in the kiln converts them into caustic lime, and whenever the water has access to the bricks, and penetrates to these nodules, the slaked lime, expanding, destroys the brick. Iron pyrites is decomposed in the same manner by the fire, and leaves cavities in the mass, giving the brick a greater tendency to fracture in those parts. Vegetal remains, roots, *et cetera*, often occasion the splitting of the bricks dur-

ing firing by the sudden evolution of gas. In the selection and mixture of the clays great care is required; clay, if too *fat*, produces bricks liable to bend and crack in the fire, and with a texture denser and less porous than is required. On the contrary, if the clay is too *poor*, the bricks will be too soft, and easily crumbled to pieces.

The manufacture of bricks may be classified under five heads—*Preparation of Brick-earth, Tempering the Mass, Moulding, Drying, and Firing.*

Preparing the Brick-earth.—The clays, after digging and weathering, as already described under *Tiles*, are classed by the brickmaker into three qualities—*strong clay, mild clay, and malm.* Strong clay in general is sufficiently free from stones to be used for the purposes of brickmaking without washing, but requires that there be mixed with the mass chalk, reduced to the consistency of cream, to counteract the warping and contraction it would otherwise undergo in the process of firing, and to improve the color of the brick. Mild clay has to be passed through the wash-mill, to free it from gravel, and other impurities, before working. The amount of sand present renders it less liable to shrink and warp than the strong clays; but its texture is so loose and incoherent, that a mixture of chalk is necessary to bind the mass together, and to take up the excess of silica in the firing. Malm is an earth suitable for making bricks without any addition, but as it now exists naturally in very limited quantities, recourse is had to the production of an artificial malm by mixing chalk and clay together, previously reduced by passing through the wash-mills. The mixture is run into shallow pits, where, by evaporation and deposit, it becomes of sufficient consistency to be worked up in the subsequent operations. This process, on account of the expense, is only adopted for the best qualities of bricks in the vicinity of London, the mass for commoner kinds being simply mixed together. The object of adding chalk to the clay is twofold—first, mechanical, by diminishing the contraction of the brick; and secondly, chemical, as a flux during the firing, by combining with the silica of the clay. A well-burnt London brick is a silicate of lime and alumina, and differs greatly from an ordinary red fired brick made without lime or alkaline matter, the silica and alumina of the brick earth in this case being only in mechanical, and not in chemical combination. The preparation of the brick earth is much the same process as that described under *Tiles*. In the midland districts the clay is generally ground and crushed between iron rollers, whereas in the vicinity of London the preparation is effected by the wash-mill, and afterwards brought to the proper consistency by evaporation in pits, and *soiled*, or covered with sifted ashes, and left to mellow.

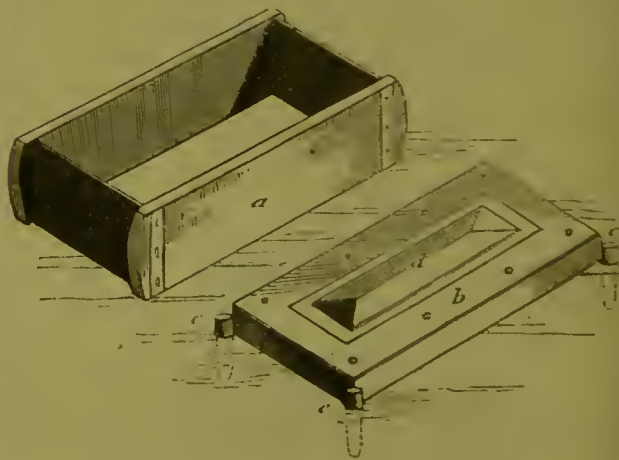
Tempering.—The *tempering* of the mass is performed in various ways, according to the practice of the locality where the bricks are manufactured. The old-fashioned way of tempering by treading consists in spreading out a moderately-thick layer of clay over a wooden floor, and kneading it well over with the naked feet, by which the workman is enabled to detect the presence of stones, roots, *et cetera*; fresh clay and

water are again added, and the operation is repeated until the whole mass becomes so stiff as to impede the action of the feet. Sand, coal-ashes, and similar additions, are sprinkled over the clay and incorporated with the mass, until the whole appears uniformly soft and moist. The extensive demand for brick generally necessitates the employment of machinery, and the *pugging* or *grinding* of the mass takes place in a mill similar to those already described under *Pottery*.

Moulding.—The moulding operation in the manufacture of bricks and tiles is simpler than that of any other kind of clay wares. The workman is supplied with a stock of prepared clay by his side, a small bench or table before him, a tub of water and some dry sand, and an assistant. Two methods of moulding are in use—*slop moulding*, where the mould is dipped in water to prevent adhesion, and *pallet moulding*, where sand is sprinkled over for the same purpose. In *slop moulding* the newly made brick is carried in the mould by the assistant to the *flat* or drying-floor, and whilst this is being done the moulder proceeds with a second mould, the first mould being returned by the time the second brick is ready.

In *pallet moulding* only one mould is used, the brick as it is formed being turned out and placed upon the hackbarrow, and wheeled away to be built into *hacks*, or low walls for drying. The mould is represented in Fig. 484TT; *a* is a four-sided frame of sheet-iron rivetted together at the angles, and strengthened with wood at

Fig. 484TT.



the two sides. The bottom of the mould is detached, and forms what is called the stock-board, *b*, consisting of a piece of wood plated with iron round the upper edge, and filling the mould accurately but easily. Four iron pins, *c c*, are driven into the moulding bench, the stock-board rests upon them, and the thickness of the brick is regulated by their height above the surface. The hollow in the bed of the brick is formed by a piece of wood, *d*, called a *kick*, of the size and shape required, and fastened upon the upper side of the stock-board. The operation of moulding is as follows:—The assistant, or *clot-moulder*, sprinkles the stool with dry sand, and, taking a *clod* or *clot* from the tempered mass, roughly kneads and moulds it into the shape of a brick, and passes it over to the moulder, who having sprinkled sand over the mould, places the clot upon

the stock-board, and dashes the half-formed mass with great force into the sanded mould; the mass which has become flattened by the shock, is forced into the angles of the mould by one or two rapid strokes of his hand; he then, with the *strike*, which has been previously wetted by immersion in the tub, removes the superfluous clay, which is received back by the elot-moulder for reworking. Finally the brick is dexterously turned out of the mould, and conveyed away, while the processes of sanding, *et cetera*, are proceeding quickly for the formation of a second brick.

The number of bricks which a workman can mould in a given time is very great, but depends very much upon the strength and ability of the operator. A moulder with proper assistance will make two thousand bricks in a working day; sometimes a much higher number is attained. The manufacture of the blue facing and paving brick is extensively carried on in Staffordshire; it possesses the same qualities as the blue pipe, ridging, and roofing tiles, and is peculiar to that locality. The annexed tabular statement received from one of the works, and showing the pieces produced there in 1859, will give some idea of the magnitude of the consumption.

STATISTICS OF A BRICK AND TILE MANUFACTORY OF
STAFFORDSHIRE.

Paving quarries,.....	1,000,000
Blue front bricks,	150,000
Paving bricks,	75,000
Roofing tiles,.....	500,000
Roofing ridges,.....	80,000
Ornamental bricks,	150,000
Front red bricks,.....	150,000
Common blue bricks,.....	620,000
Garden edging tiles,.....	25,000
Sanitary tubes,	10,000

besides large numbers of other articles not enumerated.

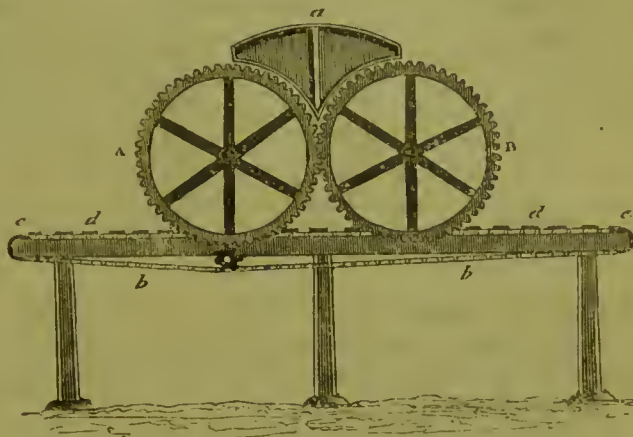
Machinery is sometimes substituted for manual labor in the process of moulding; but from the circumstance of the actual cost of moulding—about one-fourth of a penny for sixteen bricks—bearing so small a proportion to the total cost of brickmaking, it can only be employed with economy in the production of large numbers. The interest of capital, the necessity of keeping a machine constantly at work, and the cost of the motive power which such machines require, demand a very extensive market for the produce. In small brickworks, therefore, machinery effects no actual saving, and is not generally introduced for brick moulding. The mechanical contrivances for producing bricks may be classed under the following denominations:—

1. Machines with actual moulds similar to hand moulds.
2. Machines in which the moulding is performed by several moulds.
3. Machines which cut or stamp out bricks from a cake of clay.
4. Machines which produce a continuous strip or band of clay, and subsequently divide it into separate bricks.

It is unnecessary to enter into the mechanical details or respective merits of these various contrivances; the general principle being easily understood by reference to the machine constructed by Mr. HUNT, and very

generally adopted. A and B—Fig. 484UU—are two cylinders of equal diameter, geared to revolve together, and so placed as to form the front and back of the

Fig. 484uu.



hopper, *a*, the two sides of which are of iron, and arranged to form an opening at the bottom corresponding to the length of a brick, the width being regulated by the distance between the cylinders. When the hopper is filled with tempered clay, the mass forced forward through the opening by the revolution of the cylinders, will have the exact dimensions of a brick. Beneath the hopper, an endless chain, *b*, traverses over the rollers, *c c*, simultaneously with the motion of the cylinders. The pallet-boards, *d d*, are placed at given intervals, to correspond with the thickness of the brick required, and as each pallet-board arrives under the moulded mass, a wire, stretched across a frame, is brought forward and separates the brick, which is at the same time carried onwards by the motion of the endless chain—an operation repeated each time that a pallet-board comes under the hopper.

Drying.—When the bricks placed upon the drying ground in the process of moulding, have become sufficiently firm to be handled without risk of bending, they are set on edge, and piled or *hacked* in the same position until they are six or eight bricks high, spaces being left between them for the free circulation of the air through the dwarf wall thus formed. During the night, or when rain is apprehended, the walls and sides are protected with boards and straw. Sometimes during the process of drying the form of the brick is corrected in any twist by striking with a flat board; a plan that greatly improves the appearance of the brick when first admits of its adoption. Bricks that are intended to be fired in the *clamp*, require to remain in the haeks much longer than those that are fired in a kiln, from the circumstance that the firing in the clamp attains its full heat almost immediately, whereas, on account of the temperature of the kiln being capable of regulation to extreme nicety, the bricks, if *green*, can be dried in the latter by a gradually increasing heat.

An ordinary blue Staffordshire brick, wet from the mould, which weighs twelve pounds four ounces, will

weigh, when fired, only eight pounds one ounce; having lost by evaporation in the drying and burning four pounds three ounces, or thirty-four per cent. of its original weight; the specific gravity being as follows:—

Wet state from mould,	2171
Dry state, ready for kiln,	2075
Fired state,	1861

The loss in weight of a brick by drying and firing will be further illustrated by the following table:—

1850.	Hours of weighing.	Loss in ounces.	Number of hours between each weighing.	Loss of weight in ounces, during each consecutive twelve hours.
July 13.	7 A.M. weighed 196 oz.			
"	11 A.M. " 191½ oz.	4½	4	} 12 hours day, 27½ oz.
"	3 P.M. " 173½ oz.	18½	4	
"	7 P.M. " 169 oz.	4½	4	
July 14.	7 A.M. " 163½ oz.	5½	12	} 12 hours night, 5½ oz.
"	11 A.M. " 157½ oz.	5½	4	
"	3 P.M. " 153½ oz.	4½	4	
"	7 P.M. " 152½ oz.	1½	4	} 12 hours day, 10½ oz.
July 15.	7 A.M. " 150 oz.	2½	12	

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Total loss by evaporation in drying, previous to firing in the kiln, being twenty-three and a half per cent. of its original weight, and the further loss in firing amounting to fourteen per cent.

Firing or burning is performed in very many different ways, the nature of the fuel which the brick-maker has at his disposal, together with the cost and custom, being all taken into consideration. It is also considerably influenced by the nature of the work, whether stationary or changing to different places; the prices of labor, carriage, *et cetera*, likewise enter into the calculation. The burning of bricks, however, may generally be classed under two methods:—

1st. A *kiln* specially constructed for the purpose, as in the potteries, is used and charged each time with the bricks or tiles to be fired. Such furnaces may be *open, close, horizontal, or vertical*.

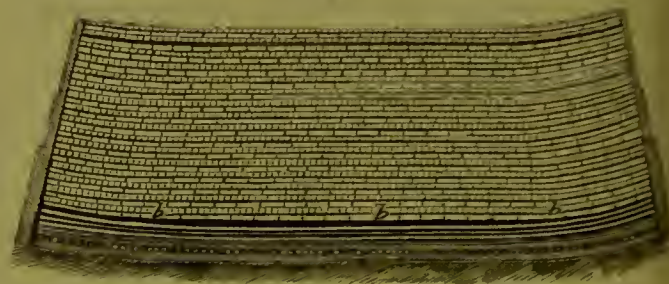
2nd. The bricks are piled one upon another to form a temporary kind of furnace, with the necessary flues; this arrangement is termed a *clamp*, and is well adapted for burning a large number of bricks at once, but not at all suitable for the finer kinds where a sharp outline is necessary.

Kilns, on the contrary, will burn all kinds of bricks and tiles equally well, but, being somewhat expensive in the construction, are only used under certain circumstances. These kilns are similar to a potter's oven, but without bags, or chimneys, or the exterior hovel, the bricks being so placed in the kiln as to form the flues to regulate the heating. In general they average from ten feet to ten feet six inches in diameter; the consumption of coal is about six tons. This construction of furnace is also modified for the firing of the better kinds of goods as well as of the salt glaze sanitary tubes now so generally used throughout England.

The process of burning in *clamps*, the great simplicity of which has given it the preference for general purposes where the locality is so far removed from any kiln as to render carriage too expensive, takes place in the open air; protection being afforded by movable straw hurdles from the too free circulation of air or wind, which might cause combustion to proceed too rapidly in one direction, and put an end to all control over the fires. The clamp, which will often comprise as many as eight hundred thousand bricks, is coated upon the exterior with loam or burnt bricks, and often occupies from eight to ten days in its construction,

according to the number of layers of bricks. Fig. 484vv represents a transverse section of a clamp; the layers of fuel used in firing the bricks, and consisting of

Fig. 484vv.



finders and small coal, are shown at *b b b*; *liveholes* or flues filled with faggots, and extending through the whole thickness of the clamp, being left to ignite the layers of *brees*, the flames from which permeate the interstices and escape at the top. The firing of a large clamp is commenced by the successive ignition of the liveholes at one end only, and, when thoroughly lighted, the mouths of the whole are stopped with bricks, and plastered over. The proportion of bree for firing every hundred thousand bricks, is generally thirty-five chaldrons sifted ash mixed with brick earth, and twelve chaldrons to light the clamp, averaging a cost of ten shillings for every hundred thousand bricks. If the proportion of bree is too small, the bricks will be underburnt, tender, and of a pale color; if too much fuel is used, there is danger of the bricks fusing and running into a kind of slag or *clinker*. The length of time of firing varies from twenty, thirty, to even fifty days, according to the size of the clamp. Bricks situated upon the outside of the clamp, and called *turnovers*, are underburnt and placed upon one side for reburning in a future clamp. Bricks situated near the livehole, and exposed to the full intensity of the fire, will be found fused into *clinkers* or *burrs*. Considerable loss occurs in this particular, the clinkers and adjacent bricks being firmly fused together, and attached to the base of the clamp, from whence they can only be removed with crowbars at considerable cost of labor. The loss by fracture, clinkers, *et cetera*, averages about ten per cent. The different qualities of bricks may be known by their color in the firing, and a very important part of the brickmaker's business

consists in sorting the bricks as they are removed from the kiln or clamp. The hard-baked bricks, generally of a dark greyish-brown, are employed for outside work, the well-baked bricks of a red color for walls, while the half-baked yellowish-red or yellow bricks are used for interior work. The harder that bricks are burnt the more sonorous they become when struck, and *vice versa*; they also last longer when exposed to frost than those which are less burnt.

The several descriptions of brick made for the London market may be classified as follows:—

FIRST QUALITY—MALMS.

Cutters are the softest, and used for gauged arches and other rubbed work.

Malms—Best building bricks, used only in fine brickwork; color, yellow.

Seconds—Sorted from the best qualities, and used for fronts of buildings of a superior class.

Paviors—Excellent building bricks, sound, hard, well-shaped, and a good color.

Pickings—Good bricks, but soft and inferior to paviors.

Rough Paviors—Roughest sortings from the paviors.

Washed Stocks—Bricks in common use for ordinary brickwork, the commonest description of malms.

SECOND QUALITY—COMMON.

Grey Stocks—Good bricks, but of irregular color, and not suited for face work.

Rough Stocks—Irregular as regards shape and color, but hard and sound; not suited for good work.

Grizzles—Tender, only fit for inside work.

COMMON QUALITY—INFERIOR.

Place Bricks—Only fit for common purposes, and not for permanent erections.

Shuffs—Unsound and *shuffy*, full of shakes.

Burrs or Clinkers—Used for artificial rockwork, cascades, *et cetera*.

Bats—Refuse.

Bricks are often adapted in shape to the purposes for which they are intended, either wedge-shaped for arches, round for chimnies, or rectangles of different forms. Sometimes they are constructed as *hollow* bricks, a form which, without impairing their strength, considerably diminishes their weight and cost in transport or earriage. A peculiar kind of brick is made at Berlin from the infusorial clay on the banks of the Spree, a cubic foot of which, weighing in the crude state sixty-one pounds, is reduced by drying and firing to twenty-five pounds seven ounces. Bricks composed of this earth weigh only one-fourth that of ordinary bricks of the same size. Bricks of this material, and containing ten per cent. of clay, were used for building the Museum in Berlin. Infusorial earth forms an admirable cement for clay in place of sand.

FIRE-CLAY goods are employed either for smelting,

as *crucibles*, or as *fire-bricks*, for lining furnaces, *et cetera*; their fire-proof qualities depending upon the amount of heat to which they are intended to be exposed, as a brick that would withstand the temperature of a limekiln may fuse in the heat of a porcelain furnace, and even those that withstand the highest temperature attained in manufactures will be fused, and frequently volatilized before the oxyhydrogen blowpipe, or between the poles of a powerful galvanic battery. As the success of smelting, and other operations in which high temperatures are required, depends so much on the material employed in the construction of the furnaces, and other apparatus, a general inquiry into this subject becomes necessary.

The fusibility of a substance is not solely influenced by the elements which enter into its composition, but also by the manner in which these elements are arranged and combined together. The chief constituent of clay—alumina—is a base which, in combination with silica, forms one of the most refractory substances, and this property is possessed by the clays in proportion as they are unmixed with other bases, as alkalies, oxide of iron, lime, and magnesia, in the order here given. In the purer clays, which for all ordinary purposes may be considered fire-proof, the refractory quality is augmented in proportion to the quantity of silica they contain.

In procuring fire-proof material, it is always desirable to obtain a chemical analysis; for, although this cannot supersede an actual trial, it is of the greatest service in guiding to the selection of the materials required to be added, in order to produce in the material the required properties. Such additions are generally necessary, as fire-clay must not only be infusible at the temperature to which it is exposed, but likewise free from liability to crack or fly, properties most important in the construction of *crucibles*. The chief cause of cracking is *contraction*, and this must be lessened by the addition of substances which do not themselves shrink, and at the same time do not impair the refractory nature of the clay. Pure sand, ground and free from lime and iron, and fire-clay previously burnt, are the substances most usually and appropriately employed. When fire-clay is brought into contact with substances exerting a chemical reaction upon it, and decomposing it by acting as a flux, it is much more difficult to obtain a ware capable of withstanding the combined action of heat and chemical affinity. An analysis of the most noted fire-clays employed in the construction of crucibles and fire-bricks is given in the annexed table:—

	Place of manufacture.	Silica.	Alumina.	Oxide of Iron.	Magnesia.
Crucibles from	Gross Almcrode	71	25	4	—
"	Paris—Beaufays	65	34	10	—
"	Saveignies, near Beauvois	72	19	4	—
"	England, for casting steel	71	23	4	—
"	St. Etienne, for casting steel	65	25	7	—
Glass pots from	Nemours	67	32	1	—
"	Bohemia	68	29	2	traces

Fire-clay wares require to be more strongly fired, in order to acquire an equal degree of solidity with those of ordinary clay—a circumstance partly occasioned by the large quantity of cement which enters into the composition of the mass. It is also of importance that the

wares acquire their maximum hardness and full amount of contraction before they are used. Crucibles do not always require firing, as is the case with the Passau crucibles, which are simply dried. Hessian crucibles, on the other hand, are burnt at about the same heat as

ordinary stoneware. The following table, according to BERTHIER, gives the elementary composition and rela-

tive proportions of the constituents in several kinds of smelting crucibles:—

Fired at 100° centigrade.	Gross Almerode.		Busufois, Département des Ardennes.		Brierly Hill, near Stourbridge.		Berthier, near Passau.	
	Berthier.	Salvetat.	Berthier.	Berthier.	Salvetat.	Salvetat.	Salvetat.	Salvetat.
Hygrometric water	—	0.43	—	—	—	—	—	0.50
Combined water	15.2	14.00	19.0	10.3	17.34	—	—	16.50
Silica	46.5	47.50	52.0	63.7	45.25	—	—	45.79
Alumina	34.9	34.37	27.0	20.7	28.77	—	—	28.10
Oxide of iron	3.0	1.24	2.0	4.0	7.72	—	—	6.55
Lime	—	0.50	—	—	0.47	—	—	2.00
Magnesia	—	1.00	—	—	—	—	—	—
Alkali	—	trace	—	—	—	—	—	—

Glass pots and retorts for the production of gas are, perhaps, the largest vessels at present constructed of fire-clay. The fire-clay retorts constructed by Messrs. JOSEPH COWEN and Company of Blaydon Burn, near Newcastle-on-Tyne, are sometimes as long as ten feet, with an internal width of three feet, and are constructed in one piece. In use they are found to be four times

as durable as iron. The material which furnishes these fire-proof wares consists of seven varieties of clay belonging to the coal formation, and which are found in the neighborhood of Newcastle-upon-Tyne. They occur below the coal, and are worked with them from the same pit. In color they are greyish-brown and full of vegetal remains. The analysis is as follows:—

	1.	2.	3.	4.	5.	6.	7.
Silica	51.10	47.55	48.55	51.11	71.28	83.29	69.25
Alumina	31.35	29.50	30.25	30.40	17.75	8.10	17.40
Oxide of iron	4.63	9.13	4.06	4.91	2.43	1.88	2.97
Lime	1.46	1.34	1.66	1.76	—	—	—
Magnesia	1.54	0.71	1.91	trace	2.30	2.99	1.30
Water and organic matter..	10.47	12.01	10.67	12.29	6.94	3.64	7.50

By this it will be seen that the amount of silica in No. 2 is to the total amount of the bases as 100:85, while in No. 6, it is as 100:16. These clays are mixed together in certain proportions according to the purposes for which they are intended. The clay is not suspended in water, the coarser particles being ground into the mass, together with the addition of one-fourth part in weight of sawdust. The gas-retorts require to resist the sudden changes of temperature, which they undergo in the processes of firing and recharging, and average three inches in thickness to give them durability. These circumstances, combined with the form of the retort, would inevitably cause them to crack, if the mass was not rendered excessively porous by the destruction of the sawdust in the firing. Powdered coke may be used for the same purpose, while the loss of gas from the porosity of the mass is prevented by the layer of carbon deposited on the interior surface during the operation. The retorts are either moulded and built up by hand with the plastic material, or formed by pressure in machines, somewhat similar to those described for pipe-making, but under pressure so enormous as sometimes to rend asunder iron cylinders between two and three inches thick. The drying and burning proceeds afterwards very slowly to avoid all chances of bursting of the retort when in use. The firing lasts fourteen days, and the retorts are of a pale-yellow color.

Newcastle-upon-Tyne also carries on an extensive trade in the manufacture of fire-bricks from the same clays above enumerated, and the preparation of which is as follows:—The clays, after exposure to the atmosphere for some time, are removed to the clay-mill, and ground up with fragments of the same clay previously burnt, from whence it is taken to the pug-mill for mastication before it is taken to the moulder. The bricks are then laid out to dry, and afterwards burnt in a kiln about fifteen feet long by fourteen feet broad, and ten feet high. Each kiln will burn

about fifteen thousand bricks at once. The operation of firing lasts five days. The bricks are placed on their edge lengthwise in the kiln. Stone-bricks of a very valuable kind, and used in the construction of the arches of reverberatory furnaces employed at Swansea in smelting copper-ores, are extensively manufactured at Neath in Glamorganshire. The materials of which the bricks are composed, are obtained from the neighborhood; they are subjected to a coarse crushing process under an edge-stone, and after mixing with a little water, are compressed into form by a machine, the coarseness of the mass rendering the moulding by hand impossible. This brick is fired in the ordinary way, but resists the action of intense heat better than the Stourbridge clay-brick. It expands more by heat, and does not contract to its original dimensions. The analysis of the three materials composing the mass is as follows:—

	From Penderyn.	From Dinns.	
Silica,	94.05	100	91.95
Alumina, with traces of } oxide of iron,	4.55	traces	8.05
Lime and magnesia,	—	traces	traces
	98.60	100	100.00

These bricks may therefore be called *siliceous* or *stone bricks*, and will no doubt prove admirably adapted for the construction of many kinds of chemical furnaces. A red fire-brick is likewise manufactured at Windsor. the analysis of the clay from which it is prepared being as follows:—

Silica,	84.65
Peroxide of iron,	4.25
Alumina,	8.85
Lime,	1.90
Magnesia,	35
	100.00

Or in mechanical mixture about seventy sand, and thirty parts clay.

QUININ.—*Quinia* or *quina*.—This important substance, which was discovered by PELLETIER in 1820, is found naturally in the bark of several species of *cinchona*, which inhabit the Eastern slopes of the Cordillera in Bolivia, Peru, and New Granada. Three principal species of bark occur in commerce—the yellow, true, or Calisaya bark, obtained from *cinchona cordifolia*; the red, yielded by *c. oblongifolia*; and the pale, from *c. condaminea*. It is found, also, though in smaller quantities, in a variety of barks, which are nearly all obtained from trees of the same family, the distinctive characteristics of which are but imperfectly known.

In the bark, quinin is associated with cinchonin, cinchonidin, cinchoninic acid, all possessing more or less basic attributes; kinic acid; cinchona red, which occurs in two forms, soluble and insoluble; a yellow and a green coloring matter; besides starch, gum, and lignin. The quinin exists partly as kinate, and partly in combination with cinchona red.

CONSTITUTION AND PROPERTIES.—Quinin is one of the more powerful organic alkalies. It generally appears, when pure, as an amorphous, resinous mass, of a dull white color. Its formula is— $C_{40} H_{24} N_2 O_4 + 6 aq.$ It may also be obtained in six-sided prismatic crystals, which are a hydrate, containing six equivalents, or 10·5 per cent. of water, which are lost on fusion.

Quinin has an intensely bitter taste; it is inodorous, and fuses readily. It dissolves sparingly in boiling, and still more sparingly in cold water. It is easily soluble in ether and in alcohol, especially if hot, and is also soluble in the essential and fixed oils.

Ammonia decomposes the salts of quinin in the cold; but on the other hand, at the temperature of ebullition the ammoniacal salts are decomposed by this alkaloid. Tartaric, oxalic, and gallic acids, and the infusion of nut-galls, precipitate solutions of its salts. Quinin menstrua, if treated with chlorine gas, become yellow, rose-red, violet, and finally deposit a red resinous matter. A solution of the sulphate, saturated first with chlorine and then with ammonia, acquires a grass-green color, and deposits a green powder. With tincture of iodine, the solution yields a clear brown liquid, which on concentration deposits saffron-colored scales of a new compound. To detect small quantities of quinin, precipitate the suspected liquid with calcined magnesia, and evaporate to dryness; then extract with one part alcohol and two parts ether. Evaporate again to dryness, and extract with ether. Now prepare a test liquor, by saturating boiling water with ferridcyanide of potassium, to which, whilst hot, are added five volumes of the strongest chlorine water, and then ammonia, until the blackish-green liquid becomes very alkaline, when the sediment is filtered off. Now mix the fluid to be tested with excess of chlorine water, and drop in the test liquor. A blood-red color indicates the presence of quinin.

Or, put a minute particle into a watch-glass, drench it with five or six drops of pure sulphuric acid and an equal quantity of water, and add a fragment of bichromate of potassa. If quinin is present, the mixture will first assume a green shade resembling that of arseniate of copper, then a beautiful yellow green, and finally a

dark green. The sulphate, similarly treated, becomes first a nickel green, next a copper green, and finally a dirty-yellow. The above-mentioned reaction with chlorine and ammonia may also serve for the detection of quinin. Quinin combines with the acids, forming a series of well-defined and persistent salts, of which the sulphate is the most important.

SULPHATE OF QUININ, usually called the *disulphate*, $HO, C_{40} H_{24} N_2 O_4, SO_3 + 7 aq.$, crystallizes in small silky tufts, or in fine acicular prisms; it has an exceedingly bitter taste, and when heated becomes phosphorescent. The dry salt is composed of one equivalent of quinin, one of sulphuric acid, and one of water. In the crystalline state it takes up, in addition, seven more equivalents, or 14·4 per cent. of water. It effloresces in dry hot air. It dissolves in thirty parts of water at 212° Fahr., but is very soluble in alcohol, especially with the aid of heat.

PREPARATION.—Quinin is generally prepared as sulphate.

The bark to be operated upon is in the first place submitted to a preliminary examination, in order to ascertain the amount of alkaloid which it contains. The safest method is to take about two pounds of bark, and to treat this by the common process for the preparation of sulphate of quinine.

GUILLERMOND proposes the following process for testing bark:—reduce the bark to powder, and treat this in a displacement apparatus with ten times its weight of alcohol of eighty per cent. Add to the alcoholic product thirty grammes of powdered quicklime for every two pounds and a quarter of bark, and agitate the mixture repeatedly. By this operation the liquor is almost completely decolorized. Filter off the sediment of lime, and add to the filtrate sulphuric acid, enough to produce the very faintest acid reaction. Distil off the bulk of the liquor, filter off the slight resinous precipitate, and concentrate the filtrate to crystallization. Others exhaust two ounces of the bark with eight ounces of water, and one scruple sulphuric acid. The mixture is kept for twenty hours at a temperature of 140°, and filtered. The digestion is twice repeated with similar quantities of acid and water. Mix and add ammonia as long as anything falls; filter, wash, dry, and weigh the precipitate. A prompt, though less accurate test, is the precipitation of a decoction of the bark by means of an infusion of nut-galls, the amount of alkaloid in the bark being estimated from the greater or less amount of the precipitate formed. The ordinary procedure for obtaining quinin is to exhaust the bark with dilute sulphuric acid, boil the extract with milk of lime, and extract the precipitate thus obtained with alcohol, from which, on concentration, the crude alkaloid separates in crystals. These are redissolved in dilute sulphuric acid, and purified by treatment with animal charcoal and recrystallization. A more perfect, though less rapid process, is as follows:—Pound the bark coarsely and let it steep in water, to which one-fifth of an ounce of hydrochloric acid has been added for every two pounds and a quarter of bark employed. Next morning boil the mixture for two hours, and strain. Submit the bark to a second and a third decoction in water containing

only half the above proportion of acid. Make, finally, a fourth decoction in pure water, and keep this for the first acid decoction of a fresh quantity of bark. The bark may now be thrown away. Mix the acid liquors, heat, and add carbonate of soda in slight excess, allowing the precipitate which forms to subside. Decant off the supernatant liquid, and test it by means of ammonia. Should this reagent produce a precipitate, the liquid must be precipitated once more with carbonate of soda. The whole precipitate is placed on a linen filter, and left to drain. It is next pressed and dried at a gentle heat. When perfectly dry it is reduced to powder, and treated from five to eight times with alcohol of eighty-six per cent., at the heat of the water-bath; squeeze the grounds each time, and filter the alcoholic liquors. The alcoholic fluid contains quinin and cinchonin, with coloring matters and some fatty substances. It is next very slightly acidulated with weak sulphuric acid, distilled, and the residue allowed to cool in the distillation apparatus.

A crystalline mass appears, which is drained on a linen cloth, to get rid of the black mother liquor. It is then washed with a little water. Make the crystalline mass, which is still highly colored, into a paste with warm water; mix with this animal charcoal in powder, and leave the paste till next morning. Mix the paste with a suitable quantity of water and boil, taking care to carry the concentration sufficiently far to obtain crystals upon cooling. For this purpose, it is preferable to divide the paste into several portions, and to treat them separately. Filter the liquid boiling. Upon cooling, the sulphate of quinin separates in perfectly white crystals. At the end of forty-eight hours let the mother liquor drain off, place the crystalline mass on some double folds of paper arranged on a hurdle, and carry them to the drying stove, taking care to keep the salt covered, since otherwise it would turn yellow. As soon as dry the salt must be removed from the stove, or it will effloresce and lose weight. The mother liquor which had deposited the white sulphate is next precipitated with ammonia, which throws down all the quinin and cinchonin still contained in it. Dissolve the precipitate with the aid of heat, in water acidulated with sulphuric acid, and add, towards the end of the operation, animal charcoal, and, if necessary, a little chalk to saturate the excess of acid. Scethe the liquid to a proper degree of concentration, and filter boiling. A fresh crop of white crystals will be deposited from the filtrate.

Treat the mother liquor of this second operation in the same way, and continue to proceed in this manner until the whole of the alkaloid is converted into crystallized sulphate. After the third precipitation it is sometimes advantageous to treat the precipitate with alcohol of sixty-four per cent., which dissolves the quinin alone, instead of dissolving it in water acidulated with weak sulphuric acid. A part of the alkaloid still remaining in the mother liquor is deposited spontaneously as sulphate, in course of time, and may be purified by the usual method. To extract the quinin still remaining in the mother liquor, the following process has been proposed by GUINOURT:—Add to the black mother liquor an equal weight of a solution of chloride

of sodium of 15° Beaumé. Boil for ten minutes, decant, and submit the brown deposit which has been formed twice more to the same operation. Pour the decanted liquors together, cool and filter, and precipitate the filtrate with ammonia. Redissolve the brown deposit which had separated from the saline liquid in the third operation in water, and add gradually, and in small portions at a time, ammoniated salt-water, taking care to stop short of complete saturation. Filter the liquid of the soft brown precipitate which forms, throw the latter away, and precipitate the filtrate with ammonia. Treat the several ammoniacal precipitates with alcohol. The solution, treated in the usual way, will now yield sulphate of quinin.

The quantities of sulphate of quinin furnished by the varieties of bark which occur in commerce are:—Two pounds eight ounces of yellow, or Calisaya bark, without rind, yield four hundred and ninety to five hundred and thirty grains sulphate of quinin. The same quantity, with the rind, yields three hundred and sixty grains. Two pounds eight ounces of the red bark, *c. oblongifolia*, will yield two hundred and forty-eight grains sulphate of quinin, besides about half that quantity of sulphate of cinchonin. Two pounds eight ounces of pale bark should yield one hundred and eighty grains sulphate of quinin, and one hundred and twenty-four grains of sulphate of cinchonin.

The following process, which has been patented by Mr. HERRING, yields a product not indeed perfectly free from color, but nowise inferior in its medical properties, and at least twenty per cent. cheaper than the common sulphate of quinin. Hence it is designated by the inventor *hospital sulphate*:—

First Operation, without Alcohol.—The powdered bark is boiled in a solution of caustic soda, pressed, returned to the boiling tub, agitated with cold water, again pressed, and if much color passes from the second washing the bark is returned to the tub, washed again with cold water and pressed once more. The treatment of the liquors obtained by the soda boilings and washings is described under the second operation. The decolored bark is now boiled with dilute sulphuric acid, kept in constant agitation by proper machinery, and this first boiling is run into the evaporating pan, a large water bath kept by steam pipes at a temperature of 120°, and agitated by the paddle wheels. The bark is again boiled with sulphuric acid and water as above, and the liquid run into the evaporating pan. The third, fourth, and fifth boilings are not evaporated, but reserved to extract the next portion of decolored bark that is brought forward. When the liquor from the first two boilings is sufficiently concentrated, it is allowed to cool, and filtered. Thus the flocculent coloring matter is separated, and the acid solution is now fit for precipitation. The filtered cold solution is treated by caustic soda, and the precipitated quinin is drained, washed, and pressed. It is now treated with dilute sulphuric acid, and crystallized into a very thick paste. When cold these crystals are pressed, washed, and again pressed. This removes the coloring matter and the chief part of the sulphate of cinchonin. The pressed cakes of sulphate are finally dissolved in a large quantity of water and recrystallized. The crystals

thus obtained from the hospital sulphate of quinin. The liquid which drains away from the second crystallization removes the small quantity of cinchonin which may not have been got rid of by the first crystallization. If the sulphate is required perfectly white it is redissolved, treated with *pure* animal charcoal, and again crystallized.

The patentee believes that in the ordinary method of making sulphate of quinin *impure* animal charcoal is absolutely necessary, though there is of course the risk of contaminating the product with the salts of charcoal.

Second Operation, with Alcohol.—The blood-red soda-boilings of the bark mentioned in the first operation are treated with hydrochloric acid, in order to retain in solution the alkaloids which have been extracted by the alkaline boilings. The ordinary view that quinin is insoluble in alkalies is pronounced erroneous by the patentee, who states, that in acting upon large quantities of bark the amount retained in solution is very considerable. The caustic alkalies exert less solvent power than the carbonates, and caustic soda least of all. After the red alkaline liquor has been acidulated with hydrochloric acid, it is concentrated and precipitated with lime. The precipitate, a mixture of quinin and lime, is washed, dried, and powdered, and finally extracted with hot alcohol. On distilling off the alcohol, the crude alkaloids are left behind. These are then treated with dilute sulphuric acid, exactly as in the former process, a larger quantity of water being required for removing the coloring matter and the sulphate of cinchonin. After two more crystallizations the sulphate is obtained perfectly pure.

The first operation yields from eighty to ninety per cent., and the second from ten to twenty per cent. of the required product.

USES.—Quinin is now very extensively employed in medicine as a tonic and febrifuge. For these purposes it is used in combination with sulphuric, citric, or valeric acid. The double citrate of iron and quinin is likewise very often prescribed.

ADULTERATIONS.—The consumption of this important remedy having greatly increased, whilst the superior varieties of cinchona bark are becoming yearly more scarce and costly, it is naturally subject to a great variety of adulterations. Amongst these may be enumerated chalk, sulphate of baryta, gypsum, boracic acid, gums, sugar, sugar of milk, starch, stearin, margarin, salicin, and phloridzin. Besides these intentional impurities, cinchonin and quinidin may be present if the preparation has not been conducted with due care. Phosphate of lime is also occasionally found, derived from the animal charcoal used in decoloring the alkaloid.

Mineral impurities may be detected by incinerating a portion of the sample in a platinum capsule. Pure quinin leaves no residue. Or a portion of the suspected quinin may be treated with alcohol at a gentle heat. Quinin dissolves, whilst any mineral matter which may be present, as well as gum, starch, stearin, will remain untouched. If a portion is burned upon platinum foil, sugar and margaric acid may be detected by their peculiar smoke and smell.

Sugar may likewise be detected by dissolving a known weight of the sample in water, and adding baryta, which precipitates both the quinin and sulphuric acid, if present. Any excess of baryta is now removed by a current of carbonic acid gas, and the liquid filtered and concentrated, when sugar, if present, is at once known by its taste. Gums and sugars may also be detected as follows:—Dissolve a weighed amount of the sample in water, and add a solution of pure carbonate of potassa, which precipitates both quinin and cinchonin. The precipitate may be filtered off, carefully dried, and weighed. Sugar and gum remain in solution. The liquid is now evaporated to dryness at a gentle heat, and the residue treated with weak spirit of wine, which dissolves the sugar, leaving gum intact. Filter off the clear liquid, and dissolve any residue in hot water. The aqueous solution is then tested with the sesquisulphate of iron, which precipitates gum as a yellowish jelly. If the sample is boiled in water, and the solution allowed to cool, starch may be detected by adding an aqueous solution of iodine, when the well-known blue or black tinge will appear. Starch, gum, and sugar may also be recognized on placing a little of the suspected sample in a porcelain capsule, and moistening with concentrated sulphuric acid. Quinin is merely dissolved, whilst starch, gum, and sugar are blackened. Ammoniacal salts are detected by triturating a portion of the sample with liquor potassæ, when an ammoniacal odor is evolved. If phloridzin is present, the sample turns a greenish-yellow in contact with sulphuric acid, and is discolored by the vapor of ammonia. If salicin be present to the extent of ten per cent. and upwards, the sample will turn a deep blood-red on the addition of concentrated sulphuric acid. In smaller proportions it may be detected by dissolving the sample in about six times its weight of concentrated oil of vitriol, and then adding twice the amount of water, when the salicin is precipitated, and may be filtered off and tested with sulphuric acid. If cinchonin be present the sample is dissolved, mixed with ammonia in excess, and well shaken up with ether. Quinin is dissolved, whilst cinchonin remains untouched, and may be separated by filtration.

The ordinary organic impurities may be detected by the following simple experiment:—A very small quantity is heated upon platinum foil, or in its absence, upon a silver spoon to fusion. Free quinin has then the appearance of oil of sweet almond; the pure sulphate a pale ruby red, the citrate a pale lemon or a deep yellow, if excess of acid be present. The valerianate remains unchanged in color. If adulterated, the residue will have neither polish nor transparency, and will be black and porous. The detection of the remaining cinchona alkaloids, if present in the salts of quinin, is more difficult. When submitted to optical tests, quinin and cinchonidin, according to BOIRCHARDAT and PASTEUR, are powerfully lævogyrate; quinidin and cinchonin pre-eminently dextrogyrate; and quinicin and cinchonin slightly dextrogyrate, upon plane-polarized light.

The ordinary tests for quinin, as mentioned above, distinguish between that alkaloid and quinidin on the one hand, and cinchonin, cinchonidin, and cinchonin on the other.

Oxalate of ammonia, when added to a solution of these alkaloids gives, after some hours, a crystalline precipitate of oxalate of quinin—if the liquid contain not less than one part of alkaloid in eight hundred of water—and a white precipitate in strong solutions of cinchonin. It does not precipitate cinchonidin or quinidin.

If hydriodic acid or iodide of potassium be added to neutral solutions, the following distinctions appear on crystallization:—The hydriodate of quinin appears as lemon-yellow prisms; the corresponding salt of cinchonidin in long thick colorless prisms; the hydriodate of quinidin in short hemihedral prisms; and that of cinchonidin in silky colorless prismatic needles.

RESINS.—*Resines*, French; *Harze*, German.—These are proximate principles found in most vegetals, and in almost every part of them; in some of them the quantity is very insignificant, whilst in others the resin is found in such abundance, as to render its extraction for industrial or medicinal purposes a profitable business, and it is to the latter class that the following particulars and descriptions apply. They are obtained chiefly in two ways; either by spontaneous exudation from the plants, or by extraction by heat and solvents. In the first case the discharge of the resin takes place, in the liquid state, from accidental punctures in the bark of the tree or shrub containing it, and also from artificial incisions penetrating the bark nearly to the hard wood. The substance which issues from these apertures is not a pure resin, but a mixture of it with volatile oil and other matters. In summer or the warm season the exudation flows freely, and the volatile oil being partly driven off spontaneously and partly resinified, the residue acquires considerable hardness. Should any of the volatile body remain, however, it is driven off on boiling, the crude matter in water, and thus the resin is obtained free from all volatile oils.

When the coldness of the season prevents the flowing of the resinous body, the method adopted for its extraction is somewhat as follows:—The ligneous matter impregnated with the resin is reduced by rasping or grinding as fine as possible, and the powder boiled with strong alcohol. Many other matters besides the resin are thus extracted, and, on adding water to the spiritous extract, partly precipitate with it. By a fractional distillation of the menstruum most of the alcohol is recovered; and during the ebullition the finely-divided particles of resin collect and agglomerate in the aqueous fluid.

Resins possess the following general properties:—They are soluble in alcohol, insoluble in water, and melt by the application of heat, but do not volatilize without partial decomposition. They have rarely a crystalline structure, but, like gums, they seldom affect any particular form. They are almost all translucent, not often colorless, but generally brown, occasionally red or green. Any remarkable taste or smell which they sometimes possess, may be ascribed to foreign matter, commonly an essential oil. Their specific gravity varies from 0.92 to 1.2. Their consistence is also very variable. The greater part are hard, with a vitreous fracture, and so brittle as to be readily pulverized in the cold. Some of them are soft, a circum-

stance probably dependent upon the presence of a heterogeneous substance. The hard resins do not conduct electricity, and they become negatively electrical by friction. When heated they melt more or less easily into a thick viscid liquid, and concentrate, on cooling into a smooth shining mass, of a vitreous fracture, which occasionally flies off into pieces like Prince Rupert's Drops; especially after being quickly cooled, and scratched with a sharp point. They take fire by contact with an ignited body, and burn with a bright flame and the diffusion of much fuliginous smoke. When distilled by themselves in close vessels, they afford carburetted acid and carbides of hydrogen, empyreumatic oil of a less disagreeable smell than that emitted by other essential oils, a little acidulous water, and a very scanty shining charcoal.

The solution of resins in either hot or cold alcohol reddens tincture of litmus, but not sirup of violet: it is decomposed by water, and a milkiness ensues, out of which the particles of the resin gradually agglomerate. In this state it contains water, so as to be soft and easily kneaded between the fingers; but it becomes hard and brittle again when freed by fusion from the water. The resins dissolve in ether and the volatile oils, and, with the aid of heat, combine with the unctuous oils. They may be united by fusion with sulphur, and with a little phosphorus. Chlorine bleaches several colored resins if they be diffused in a milky state through water. The sulphide of carbon dissolves them. Concentrated mineral acids decompose resins under the influence of heat, the agents being likewise reduced. Strong sulphuric acid dissolves them in the cold; but on the addition of water, they again separate without decomposition. When heat is applied the sulphuric acid is broken up into sulphurous acid; at the same time carbonic acid results from the resin, and a carbonaceous residue with the artificial tannin of HATCHELL remains. Nitric acid aided by heat effects several transformations in resin, according to its state of concentration and the period during which its action is continued. Some resins yield, to this treatment, oxalic acid, and invariably artificial tannin may be obtained.

Most of them dissolve in solutions of the fixed alkalies, whether hot or cold, as also in ammonia, and form definite salts—resinates—some of which are quite neutral. These resinates are soluble in water, and form a considerable portion of the cheaper kinds of soap, being themselves possessed of detergent qualities. Resinates of the alkaline earths, and of the heavy metallic oxides, may be prepared from those of the alkalies by double decomposition; but they are insoluble, and generally strong acids liberate the resin from them unchanged.

Every resin is a natural mixture of several others, which sometimes admit of easy separation by different solvents, such as alcohol, ether, essential oils, alkaline solutions, *et cetera*. For instance, when certain acid resins are dissolved in alcohol, and an alcoholic solution of acetate of copper is added, it happens sometimes that only a part of the resin is precipitated. The deposit, which can be readily separated from the liquid, is found occasionally to be but partially dissolved by

other menstrea, and consequently admits of being separated into several definite substances. Again, many resins on being treated with a solution of potassa, soda, or ammonia, do not entirely dissolve; and inferring from this that the undissolved portion has not the same properties as that dissolved, the conclusion follows that two or more distinct principles were contained in it. The soft resins, which retain a certain portion of volatile oil, constitute what are called balsams, a full description of which will be found in Vol. I., page 224, *et sequitur*.

According to DUMAS the resins may be arranged in five classes, namely:—

1. Those which yield a volatile oil on being distilled with water, and leave an acid resin, or rather several resins possessed of acid properties, in the retort. To this class belong the several turpentine resins, balsam of copaiba, *et cetera*.

2. Those which yield a volatile oil when distilled with water and one or more acid resins, as in the foregoing; but in addition, a neutral one, generally capable of being crystallized. Animi, elemi, and caranna resins, mastic, vegetal, or palm wax, and several others, are of this order.

3. Resins which do not furnish a volatile oil on being distilled with water. Such are copal, amber, lac, betulin, and the like.

4. Resinous matters containing substances soluble in water of the nature of gum. Many of the members of this group have been already described as gum-resins, under GUMS, to which the reader is referred.

5. Balsams or compounds which contain, besides a volatile oil and an acid resin, cinnamic or benzoic acids, or some substances capable of producing them. It will be unnecessary to follow the description of the subjects coming under this class here, as they have been already described at some length.—See BALSAMS.

The Editor will now glance cursorily at each variety of resin in its alphabetical order, space not permitting of more.

AMBER.—*Succin*, French; *Bernstein*, German; *Succinum*, *Electrum*, Latin.—This interesting substance is frequently included among minerals, with which, however, it can no more be classed than the resin copal found in the sands of Africa. It is a substance of vegetal origin, resembling copal and other resins in appearance, and in some of its physical and chemical properties, and, like them, is employed for varnishes. The variation of its properties from those of ordinary resins is not, perhaps, greater than is to be found among the different members of the class, and may be in part attributed to a slight and gradual alteration effected during the time of its exposure to the various natural agents. From some of its chemical and physical properties and its occurrence in or near coal or lignite, it is usually supposed to be a resin derived from trees of the same geological age with the upper, secondary, or tertiary strata; but from the formation of succinic acid from fat, as well as from amber, one might suppose it to have been a species of wax, or to have a fatty nature. Its balsamic or resinous origin is more probable than the latter view. According to the traditions of the ancient Celtic nations, amber signifies tears shed by

APOLLO on leaving heaven for the famed Hyperborean island—Erin—and the account is thus happily recorded by BRYANT:—

The Celtic sages a tradition hold,
That every drop of amber was a tear
Shed by AROLLO when he flew from heaven;
For sorely did he weep, and, sorrowing, passed
Through many a doleful region, till he reached
The sacred Hyperboreans.

Amber is most abundantly found on the Prussian coast of the Baltic, Courland, Livonia, Pomerania, and in Denmark, where it is often washed up on the shore by the waves, after the autumnal storms; or it is dragged up by a net, or obtained by mining. In the latter case a stratum of sand, then of loam, are pierced, neither containing amber; but below the latter occurs a bed of lignite, in and near which it is obtained. From the cones found near it, one may attribute the amber to the balsam of certain extinct species of coniferæ, which has hardened by the loss of its volatile oil. It frequently contains insects of various genera and species; among them several genera of spiders, no species of which is now in existence. Some genera of these insects are still found in South America and New Holland, but the species are extinct; and but a single living insect found in America has been observed in amber, namely—*lepisma saccharinum*. It is sometimes, but rarely, found on the Scandinavian coast; other localities are Hasen Island, Greenland, near London in sand, and Paris in clay, in Italy, on the Sicilian coast, in Spain, Siberia, China, and the United States, where it occurs in the red clay formation subjacent to the green sand, and sometimes in the green sand itself.

Thus it occurs frequently associated with lignite on Martha's Vineyard; from Amboy to below Camden, New Jersey; in the clays and sands of the deep cut on the Delaware and Chesapeake Canal, and in the green sand in Delaware; further at Cape Table, Maryland. It is said that Prussia draws an annual revenue of seventeen thousand rixdollars from this substance.

It is found of variable sizes; a specimen in the royal collection at Berlin weighs eighteen pounds. It is sometimes colorless, though usually some shade of yellow, light and brownish yellow, reddish-orange, brownish-black; it is transparent, translucent, opaque, sometimes milk-white and opaque, different hues and degrees of transparency occurring in the same piece; it has a resinous lustre, is rather brittle, has a conchoidal fracture, and a soft-feeling shining surface; it receives a good polish, and hence is carved into ornaments.

Specific gravity 1.065–1.075. By friction on woollen cloth it becomes strongly negatively electric.

Heated in the air it fuses at about 549°, evolving an agreeable aromatic odor, and burns with a clear flame. By fusion it is decomposed and its properties altered, giving off volatile matter and leaving a clear brownish translucent resin, which is almost insoluble in alcohol, partially soluble in ether, and most perfectly in fixed and volatile oils, with a brownish-yellow color. Slowly heated in linseed oil to boiling, it is soft and flexible, without fusing or decomposing, and, unless cooled slowly in the oil, is as brittle as glass; opaque spots are thus often rendered translucent.

Amber is wholly insoluble in water; absolute alcohol and ether become yellow in contact with it; when used on the substance powdered they extract succinic acid and resin.

It is soluble, with a brown color, in strong sulphuric acid from which water precipitates the greater part of a yellow color, which retains a little of the acid; by boiling with the same acid tannin and charcoal are produced. Nitric acid changes it to a yellow resin, which gradually dissolves in the acid. Finely powdered, and boiled with solution of caustic or carbonated alkali, much succinic acid is removed; and pure water extracts a resinate of the alkali from the residue, leaving amber bitumen.

By destructive distillation in a closed vessel an acid liquor containing acetic and succinic acids passes over; some crystals of succinic acid are then deposited in the neck of the retort, after which an empyreumatic oil is disengaged, at first thin and yellowish, but subsequently brown and thick; finally, a light-yellow wax-like sublimate appears in the neck of the retort, to which BERZELIUS has given the title of *crystallized pyréline*, and GMELIN amber-camphor. The proximate constituents of amber are a volatile oil, succinic acid, two resins soluble in alcohol and ether, and a bituminous insoluble substance which constitutes the chief bulk of it; its ultimate analysis showed it to consist of carbon, hydrogen, and oxygen in the following proportions:—

	Centesimally.	
	Drassier.	Ure.
Carbon,	80.59	70.68
Hydrogen,	7.31	11.62
Oxygen,	6.73	7.77
Ash,	3.27	} 9.93
Loss,	2.10	
	100.00	100.00

USES.—Fine amber is used for making trinkets and ornamental objects; but its estimation is much greater in this respect in Oriental nations than with Europeans. The portion designed for ornamental work is split on a leaden plate on a lathe, and then smoothened to a shape on a Swedish whetstone; it is then polished with chalk and water or vegetal oil, and finished by rubbing with flannel. In these processes the amber is apt to become highly electrical and very hot, so much so as to produce nervous tremors in the wrists and arms of the workmen from the electricity. The artists guard against these effects, however, by working the pieces in rotation, so that the heat may not increase to an injurious degree, and the amber remains only feebly excited. The coarser kinds of amber are employed in chemical and pharmaceutical operations, and also for the manufacture of varnishes.

ANIME.—A resin not unlike copal, and of which there are two varieties, the American and the Oriental. The American anime is said to flow from incisions in the *hymenaea courbaril*, a tree growing in Brazil, Virginia, and the West Indies. The purer resin occurs in pale yellow pieces, with a vitreous fracture and dusty surface; softens in the mouth, tastes like mastic, and has an agreeable odor, especially when heated; specific gravity 1.03; combustible, and gives a lively flame. Warm oil of olives or lavender dissolves it;

it is wholly soluble in boiling alcohol, the solution reddening litmus, although the acid is scarcely extracted by water. Cold alcohol separates it into two resins; the soluble—54.3 per cent.—resembles the resin itself; the difficultly soluble resin—42.8 per cent.—precipitates from a boiling alcoholic solution, drying to a tasteless mass, slightly odorous and lighter than water. It also contains about 2.4 per cent. of a volatile oil, which passes off by heating *per se*, or with water. A brown variety does not soften in the mouth.

The Oriental anime, which has a specific gravity of 1.0272, appears to be a mixture of two resins, one pale yellow, brittle, not softening in the mouth; the other reddish-yellow, softer; it does not contain the difficultly soluble resin, and its alcoholic solution has a less acid reaction. It is not decomposed by nitric acid, even at the heat of fusion.

Anime was formerly employed in pharmacy, but is now chiefly used for scenting pastilles, and for varnishes; but it is rather a bad material for the latter, as it is dried with difficulty, and leaves the coating soft and pasty. For these reasons it is never used *per se*, but in admixture with other more suitable resins.

Botany Bay Resin, said to be the produce of *acarois resinifera*, is of a yellow hue, brittle, and of a slightly astringent taste. It exhales a fragrant odor when heated, and dissolves in alcohol and ether. It resembles tolu balsam in containing cinnamon, and a small quantity of benzoic acid.

COLOPHONY.—*Common Resin*.—This is the residue remaining on the distillation of common turpentine; it retains more or less water, and is known as white and yellow resin, being in this state translucent, and often slightly viscid. When deprived of water by fusion, it is termed brown or black resin, colophony, rosin, or fiddler's rosin.

Rosin is a brittle, tasteless, and almost inodorous substance, of a smooth shining fracture; its specific gravity is 1.080. It softens at 160°, but does not enter into fusion under 275°. According to the analysis of BLANCHET and SELL, this substance, in its pure state, may be represented as composed of $C_{40}H_{30}O_4$; but UNVERDORFEN has shown that colophony includes two distinct acid resins, together with a minute portion of an indifferent one. These acid resins he designates pinic acid, and silvic acid, the former greatly preponderating. As respects the composition of these acids, it appears that they are isomeric, and therefore have the same formula as that above ascribed to pure colophony, a conclusion sanctioned by ROSÉ and TROMMSDORFF, but not by LÖWIG.

Rosin forms an important ingredient in the composition of yellow soap, and is a partial substitute for fixed oil or fat; it is not analogous to the latter in chemical constitution, nor can it, like those bodies, form with an alkali a proper soap by itself. Colophony contains no glycerin, nor any equivalent for that substance.

The formation of yellow soap from rosin depends on the direct combination of the resin acids with soda. No glycerin is eliminated, there being no proper saponification. The compounds formed, however, by the union of soda with rosin are not separable from their

aqueous solutions by chloride of sodium, like true soda soaps, nor do their concentrated solutions become mucilaginous or gelatinous on cooling, nevertheless they produce a lather, and, when added to soap in limited proportion, increase its detergency. Rosin is also used to some extent in perfumery.

This resin is largely employed in manufacturing industry for the purpose of extracting the various oily bodies it produces by destructive distillation, and which oils are largely consumed in the arts, as well alone as for adulterating dearer kinds. The bleaching of common colophony has long engaged attention, but success did not attend the various efforts. Latterly, however, Messrs. HUNT and POCHIN's patent seems to have accomplished the task of converting the common black resin, worth four to five shillings per hundredweight, into a white almost transparent compact article, which is said to be highly beneficial to soap and varnish makers, and worth as much as fifteen shillings per hundredweight.

Their process may be here advantageously although cursorily described. It consists in distilling resins and resinous substances without decomposition, or only partially so, by which they are freed from various mechanical impurities, and at the same time almost deprived of their color. The ordinary rosin of commerce, *et cetera*, are taken and introduced into an iron or other suitable vessel; they are then melted, and steam is passed, during the entire period of the operation, through the fluid mass, until the whole, or nearly the whole, has been distilled. The rosin is condensed in a suitable receiver, kept as cold as it can be by the application of water, and exsiccated; it is then adapted for the purposes for which it is required. During the distillation the temperature rises from about 390° to 600°, at which it is maintained until all such portions of the contents of the still as are capable of being volatilized have passed into the receiver. Instead of steam, carbonic acid, or a mixture of carbonic acid and nitrogen, or hydrogen gas or carbides of hydrogen, are introduced to decolor the resin.

COPAL, said formerly to have been derived from *rhus copallinum* and the *elæocarpus copalifer*, seems by late accounts to be obtained from various species of *hymenæa trachylobium* and *vonapa*. Several varieties of this resin are known in commerce, which are apparently the product of different trees, natives of Africa, America, the East Indies, and New Zealand. Levant copal is considered the best, and is met with in moderate-sized round masses, hard, transparent, colorless, or but slightly lemon yellow. *It is, of all resins, that which makes the finest varnishes.* Two kinds of copal resin are known; one hard or true, and the other tender or fictitious copal. The true variety, as above stated, is met with in large pieces, colorless, or of a slight yellow shade, exteriorly opaque, but limpid in the interior. In some cases its tint approaches to a brown. Insects are occasionally found inclosed in it, but more rarely the debris of plants.

It has so much resemblance to amber that it might be supposed to have a fossil origin; at all events it has probably been long exposed to the action of the air before being collected. It is very hard, and breaks

with a conchoidal fracture. Exposed to heat it softens, but does not permit its being drawn into threads; when the temperature is more elevated it melts, and at the same time undergoes decomposition, and distributes on boiling a vapor having the peculiar odor of the wood of the aloe tree. Its specific gravity varies from 1.045 to 1.139. In the natural state copal is only slightly soluble in absolute alcohol; on boiling it, however, it tumefies, and forms a viscous elastic mass; with ether it acts in a similar way, but ultimately dissolves. When it is desired to dissolve it in alcohol *per se*, the best method is to suspend it in the vapor of the boiling liquid, and it gradually falls drop by drop and is perfectly dissolved; with oil of turpentine, under similar treatment, the result is the same. To avoid the loss of spirit and other inconveniences which attend this process, many trials have been made. One of these, though singular, is said to be effective; it is to grind the resin and expose it to the air for a period of ten or twelve months, after which it is readily taken up by spirit of wine. It may be dissolved in absolute alcohol by first acting on it with ammonia, which softens it into a gelatinous mass, and then adding the spirit in small portions, with the aid of heat. It may likewise be dissolved in alcohol after being softened with ether.

The ordinary practice is, however, to take advantage of the property which certain essential oils have of softening the resin, and thereby rendering it more readily soluble. A quantity of the copal is taken and moistened with oil of rosemary or of lavender; after standing for a time some pieces begin to soften, while others are unaffected; the former are selected for spirit varnish, and the latter are put by for varnish to be made with fixed oils. The first portion is then ground, moistened a second time with either of the essential oils named, and after a short time it swells up to a pasty mass, which on addition of the necessary quantity of spirit of wine dissolves. Spirit of turpentine behaves in like manner. The same menstrua, provided a little camphor be first dissolved in them, readily take up the resin; but the varnish thus formed, as also that prepared by means of oil of rosemary, is soft and devoid of the durability which the real spirit varnishes made with the resin possess. But the common copal varnish is made by melting it cautiously, and adding oil of turpentine heated to a certain point.

According to UNVERDORPEN and FILHOL, who have more recently examined Indian copal, it contains no less than five definite compounds of a resinous nature, four of which possess acid and one neutral properties. Thus, in treating powdered copal with a spirit containing sixty-seven per cent. of alcohol, and adding to the extract thus obtained an alcoholic solution of acetate of copper, a precipitate of bluish flocculi appears, which on being dried and affused with cold ether takes up resin A; the alcoholic liquid retains resin B in solution. Further, on treating the residue with absolute alcohol, a third resin, C, is dissolved together with portions of the two preceding ones; and, finally, by treating what remains from the last menstruum with potassa, a fourth resin, D, separates, and a neutral substance, E, remains.

The analysis of copal, according to FILHOL, is as follows:—

	Bombay copal.	Madagascar copal	Calcutta copal.
Carbon,	79.70	79.80	80.66
Hydrogen,	9.90	10.78	10.57
Oxygen,	10.40	9.42	8.77
	100.00	100.00	100.00

The composition of the resin alters, however, on being exposed to the air for some time in a finely-powdered state, or when reduced to an impalpable powder by abrasion under water, oxygen being absorbed, as the following analyses illustrate:—

	Copal exposed to the air in fine powder.	Copal reduced to an impalpable powder under water.
Carbon,	77.0	71.4
Hydrogen,	10.0	9.2
Oxygen,	13.0	19.4
	100.0	100.0

Tender or fictitious copal is found in commerce mixed sometimes with a little Indian copal, but it is brought from the Brazils without any admixture. That from India is vitreous, translucent, and nearly as transparent as glass, but age communicates to it a shade of yellow on the surface. Its ordinary form is in tears; it possesses a weak, agreeable odor, is very friable, and preserves this property even in the varnish made with it, on which account it is not so much esteemed. Heat renders it soft and elastic, so that it can be drawn out into threads as fine as silk. Alcohol partly dissolves it, the residue appearing like gluten. Ether takes up nearly the whole substance.

FILHOL has analyzed this resin and found it gave—

Carbon,	85.3
Hydrogen,	11.5
Oxygen,	3.2
	100.0

Dammara Resin is a white resin brought from the East Indies, and is said to be the produce of the *pinus dammara*; it contains a resin soluble, and one insoluble in alcohol.

Dragon's Blood, which is a deep-red resin imported from the East Indies, has been fully described, although erroneously, under BALSAMS, in vol. i., page 227.

ELEMÍ.—It appears that the source from which this resin is obtained is very doubtful. It is generally described as constituting a member of the *Amyrideæ*, which is allied to the class to which the orange-tree belongs, owing to LINNÆUS confounding apparently two distinct plants under one name—the *amyris elemifera*—namely, the *icica icicariba* and the *amyris plumieri* of DE CANDOLLE; the former a Brazilian tree which yields, according to PISON, a resin similar to the so-called *gum-elemi*, and the latter a native of the Antilles, which likewise produces a resin. PEREIRA, in tracing the source and origin of this resin, found that it was imported entirely from Amsterdam and Hamburg, and concluded that it was the product of a Dutch settlement. He is inclined to believe that which formerly came from Ethiopia by way of the Levant was derived from the *canarium zephyrinum* or *canari*

barat of RUMPHIUS, who says that it yields a resin so like elemi that it might be taken for it. PEREIRA mentions three kinds of elemi—elemi in flag leaves, elemi in lumps, and Brazilian elemi. The first is imported into England from Holland in triangular pieces of one to two pounds weight, enveloped in palm leaves. The elemi in lumps is a little paler in color than the Brazilian. MARTIUS states that the first variety is the product of the *amyris zeylanica*; though PEREIRA doubts the assertion, on the ground that if it were a product of Ceylon it would be imported direct hither, which is not the case. The only doubt which seems to throw upon the Brazilian elemi being derived from the *icica icicariba*, which may be taken for the *amyris elemifera* of LINNÆUS, rests upon the certainty of its being a Brazilian product.

In extracting the Brazilian elemi, an incision is made into the stem of the tree, whence the juice exudes, and the resin is gathered in twenty-four hours afterwards. It is imported in cases containing two or three hundred pounds each. It is soft and unctuous, but becomes hard and brittle by cold and age. It is semitransparent, of a yellowish-white color, mixed with greenish points; its odor is strong, agreeable, analogous to that of fennel. This is owing to a volatile oil, which may be obtained from it by dry distillation.

The description most extensively dealt in, is that which is brought to this country from Singapore in a soft, strong-smelling mass, in cases of about two hundredweight. It is the produce of Manilla, and the Editor is credibly informed that it is not imported from any part West of Singapore. In addition to this, the Brazil sort is occasionally seen in the market.

The proximate principles of elemi are a transparent resin having acid properties, soluble in cold alcohol; a second resin taken up by boiling alcohol, but deposited from the solution on cooling in a crystalline state; a volatile colorless oil, which, according to DEVILLE, resembles much the essence of turpentine, and of citron in composition, as in its reactions; and a bitter extractive. The annexed per centages were found by BONASTRE:—

Volatile oil,	12.5
Resins soluble in both hot and cold alcohol, . . .	60.0
Resins soluble in hot, but not in cold alcohol } —elemi,	24.0
Bitter extractive,	2.0
Impurities,	1.5
	100.0

The resin *a*, readily soluble in cold alcohol, consists, according to JOHNSTON, of $C_{40}H_{32}O_4$, while the resin *b*, sparingly soluble in cold alcohol, is composed of $C_{40}H_{32}O$. Specific gravity, 1.08 BONASTRE; SCHUBART gives it 1.055.

Elemi is occasionally used as a topical remedy in the form of an ointment, more particularly in ulcerous complaints of an old and indolent nature. It is extensively employed for varnishes.

GUAIACUM.—This substance, which is commonly, though very erroneously, denominated gum-guaiacum, is the produce of the *guaiacum officinale*, a lofty tree, native of St. Domingo and Jamaica. It occurs in tears naturally exuding from the stem; and in lumps ob-

tained partly from incisions into the trunk of the tree, and partly by the action of heat upon billets of the wood. This resin is of a dark-green diugy color, transparent when in thin laminae, and of a brilliant resinous fracture. It has a slight balsamic odor. Its powder is at first pale grey, but gradually deepens, and becomes green by exposure: it acquires a beautiful but transient blue tint when moistened with spirit of nitrous ether. According to the Edinburgh Pharmacopœia, the characters of guaiacum resin are as follows:—Fresh fracture red, slowly passing to green; the tincture slowly strikes a lively blue color on the inner surface of the paring of a raw potato. The specific gravity of guaiacum varies between 1.20 and 1.23. It is soluble to the extent of about ninety per cent. in absolute alcohol. The insoluble portion, though sometimes described as resin, has more of the characters of altered extractive. When subjected to dry distillation, guaiacum fuses at about 570°, and an oily matter, together with water, passes over, which has been examined by SOBRERO, and by PELLETIER. When chewed, guaiacum softens under the teeth, but has scarcely any taste, though it leaves a burning sensation in the throat.

Physiological Effects.—Guaiacum resin is an acrid stimulant, formerly very much used in medicine, and even now to a great extent.

Under the use of small and repeated doses of guaiacum various constitutional diseases sometimes gradually subside, and a healthy condition of the system is brought about with no other sensible effect of the remedy than perhaps the production of some dyspeptic symptoms, and a slight tendency to increased secretion. One designates this inexplicable, though not less certain, influence over the system by the term *alterative*. When guaiacum is given in *moderately large doses*, or to plethoric, easily excited individuals, one observes the combined operation of an acrid and stimulant. In very large doses guaiacum causes heat and burning in the throat and stomach, vomiting, purging, pyrexia, and headache. In its operation on the system guaiacum is allied to the balsams.

JALAP.—The resinous portion of jalap is the most important. Jalap resin is obtained by mixing the alcoholic tincture of jalap, prepared by percolation or digestion with water. The precipitated resin is to be washed with warm water, and then dissolved in alcohol. By evaporation the tincture yields the resin. PLANCHÉ has proposed another process. By digestion with animal charcoal, the alcoholic solution of the resin is rendered nearly colorless, and by evaporation yields an almost colorless resin. Jalap resin is soluble in alcohol, but insoluble in water. Triturated with milk it does not form an emulsion, but its particles unite into a solid mass. By this it may be distinguished from scammony resin.

Physiological Effects.—Jalap resin is a local irritant. It acts as a powerful and drastic purgative. To scammony it is closely allied, not only by its effects, but also by botanical affinities and chemical properties. It is much less irritant to the intestinal mucous membrane than gamboge; and, therefore, is a much safer purgative.

Adulteration.—Commercial resin of jalap is rarely,

if ever, obtained in a state of purity. Guaiacum resin is the substance most frequently found mixed with it. Two methods have been pointed out for detecting this fraud—one by means of ether, the other by nitrous gas. Ether dissolves guaiacum very well, but does not dissolve resin of jalap. With nitrous gas the process consists in dissolving a small quantity of the suspected resin in spirit of wine, soaking a piece of white paper in this liquid, and exposing the paper to the action of nitrous gas. If the alcoholic solution of resin of jalap contain guaiacum, the paper should assume a blue tint; if no guaiacum be present, the color will remain unaltered.

MASTIC is the produce of the *pistacia lentiscus*, native in the South of Europe, the North of Africa, and the Levant, particularly the Island of Chios. It occurs in small spheroidal translucent tears, of a pale yellow hue, vitreous fracture, agreeable odor, and mild aromatic taste. When chewed, it becomes tough and somewhat viscid; it fuses at about 250°, and begins to be decomposed; it contains a very minute quantity of volatile oil. Mastic is a valuable ingredient in certain varnishes, and is frequently used for the purpose of stopping decayed teeth. It is not employed in medicine. Its produce is commonly known under the name of *pounce*.

SANDARACH, or Juniper resin, is the produce of *thuja articulata*, which grows in Barbary. It is imported from Magadore, and largely used as an ingredient in varnishes. It usually occurs in small yellow brittle drops, easily fusible, and soluble in alcohol.

SCAMMONY RESIN.—The substance known in pharmacy under the name of *scammony*, is an exudation from incision of the root of the *convolvulus scammonia*, and appears first as a milky juice, which afterwards dries. It is often very considerably adulterated. Several varieties of this drug come into the market, but the most select is imported from Smyrna, and occasionally from Trieste, under the name of *virgin* or *lachryma scammony*. It is of a dark-greenish grey color, moderately hard, and of a somewhat resinous fracture. It should not effervesce with hydrochloric acid, nor should its cold filtered decoction be blueed by iodine. One hundred grains, when incinerated with nitrate of ammonia, should not yield more than about three grains of ashes: ether should abstract from it at least seventy-eight per cent. of resinous matter. The odor of scammony, especially when breathed upon or moistened, is peculiar; and when a little water is rubbed upon its surface it should easily lactify.

THE RESIN OF SCAMMONY, obtained by evaporating its ethereal solution, is transparent, and of a brown tint, but may be decolorized by animal charcoal. Its alcoholic solution is feebly acid, and water throws down from it the resin in the state of hydrate. According to JOHNSTON, it is remarkable as containing more oxygen than any other resin hitherto analyzed. It is a powerful cathartic.

LAC.—*Laque*, French; *Gummilack*, German.—This resin is produced by the female of a small insect—the *coccus lacca*, or *coccus ficus*—which feeds and fecundates upon the banyan or religious tree of the Hindoos, and several allied plants, such as the *ficus indicus*, *ficus*

religiosa, the *rhamnus jujuba*, the *croton lacciferum*, and the *butea frondosa*.

In November or December the young brood makes its escape from the eggs lying beneath the dead body of the mother; they crawl about a little way, and fasten themselves to the bark of the shrubs. About this period the branches swarm to such a degree with the vermin that they seem covered with a red dust, in which case they are apt to be dried up and exhausted of their juico. Many of them, however, adhering to the feet of birds, become their prey, and are carried off by them to other trees. They soon produce small nipple-like incrustations upon the twigs, their bodies being apparently glued by means of a transparent liquid, which goes on increasing to the end of March, so as to form a cellular texture. At this time the animal resembles a small oval bag, without life, of the size of the cochineal. At the commencement a beautiful red liquor only is perceived, afterwards eggs make their appearance. In October or November, when the red liquor becomes exhausted, twenty or thirty young ones bore a hole through the back of their mother and come forth. The empty cells remain upon the branches; they are composed of the milky juice of the plant which serves as nourishment to the insects, and which is afterwards transformed into the red tinctorial matter which is found mixed with the resin; but its quantity is greater in the body of the insect than in the eggs, and more particularly in the red liquor secreted for feeding the young. After the escape of the insect the cells contain much less coloring body, and, consequently, the collection of resin ought to take place before that time by breaking off the twigs and drying them in the sun. In the East Indies this operation is performed twice in the year—the first time in March, and the second in October.—*Urc.*

The dried branches and twigs are called *stick-lac*, which serves the double purpose of dyeing, varnish-making, and sealing wax.

There are several varieties of stick-lac. According to quality that of Siam is considered the best, the Assam stick-lac ranking next, and the third quality is produced in Bengal. The analyses of the stick, seed, and shell lac are here collated:—

	John. Stick-lac.
An odorous resin,.....	66.65
Resin insoluble in ether,.....	16.75
“ laccin,.....	
Coloring matter,.....	3.75
Laccic acid,.....	0.62
Extractive,.....	3.92
Skins of insects,.....	2.08
Wax,.....	1.67
Salts,.....	1.04
Sand,.....	0.62
Loss,.....	2.90
	100.00

	Hatchett.		
	Stick-lac.	Seed-lac.	Shell-lac.
Resin,.....	68.0	88.5	90.9
Coloring matter,....	10.0	2.5	0.5
Wax,.....	6.0	4.5	4.0
Gluten,.....	5.5	2.0	2.8
Foreign bodies,.....	6.5	0.0	0.0
Loss,.....	4.0	2.5	1.8
	100.0	100.0	100.0

Lac as brought to Europe is in various forms, such as grains, lumps, and thin scales; the former is called *seed-lac*, and is the residue after the resinous matter scraped off the stick-lac, ground and boiled in water to remove the greater part of the coloring matter, and dried in the sun; the second is called *lump-lac*, and is merely the former melted into lumps; and the third, which is named *shell-lac*, is of the same nature as the seed and lump-lac, only purer. It is usually prepared in India by heating the seed-lac in bags over a fire, and by squeezing and pressing, causing the liquefied resin to flow out and fall upon the smooth surface of the stems of the banyan-tree; the coatings thus formed on cooling harden and constitute shell-lac.

It will be seen from the preceding tables that the proportion of resin is much larger in shell-lac than in any of the other commercial forms of the resins. The better quality of the article is of a light-brown hue passing into orange, and sometimes to a deep ruby color, whence the names *orange* and *ruby* shell-lac; the inferior kinds are much less transparent, darker in color like glue, and in thicker plates.

By exposure in thin shreds to the sun's rays, or in a finely-divided state to chlorine water, or by reducing it to a fine powder, suspending in water and passing hydrochloric acid vapor into the menstruum, the dark-colored varieties are bleached. When this is done, however, the resin loses many of those qualities that so admirably recommend it for some kinds of varnishes, but it answers well for making sealing-wax.

Lac resin is very difficultly soluble in alcohol, though, like copal, it may be completely taken up by this solvent. Like most of the other resins, it has a strong affinity for bases, with which it forms definite compounds. Dilute hydrochloric acid and acetic acid dissolve the resin freely, but not the strong sulphuric acid. Borax solutions with the aid of heat also take it up. The portion soluble in alcohol has a specific gravity of 1.139. UNVERDORPEN found it to be a compound of several resins, namely—

1. Resin soluble both in alcohol and ether. 2. Resin soluble in alcohol, insoluble in ether. 3. Resin but very slightly soluble in cold alcohol. 4. Crystallizable resin. 5. Resin soluble both in alcohol and ether, but not in petroleum uncrystallizable. Besides these, a saponifiable fat wax and coloring matter have been detected in shell-lac.

SILVER.—*Argent*, French; *Silber*, German; *Argentum*, Latin.—This is one of the precious metals, and is characterized by its perfectly pure white color. Its combining weight is 108; its symbol, Ag. Melted, its density is 10.47: hardened under the hammer, it becomes 10.54. Its specific heat is 0.057. In malleability it is only inferior to gold, and may be beaten into leaves of less than one-hundred-thousandth of an inch in thickness, and drawn into very fine wires. It has also considerable tenacity, a wire of one-hundredth of an inch in diameter supporting a weight of twenty-three pounds. It is harder than gold, but softer than copper, and when pure it is so soft as to be cut by a knife. The addition of a small quantity of copper increases its hardness.

Silver melts at a full red heat, corresponding to

1870°; but in consequence of its pure white color, and the high lustre which it is capable of receiving, its reflecting power for light and heat is greater than that of any other metal, and, therefore, when perfectly polished, it does not melt in the focus of a mirror capable of fusing platinum. For the same reasons, its radiating power is so low that a silver vessel retains the heat of a liquid contained in it longer than a vessel of any other metal.

HISTORICAL NOTICE.—The discovery of silver appears to have been coeval with that of gold, and dates back to the earliest times of human history. In the book of Genesis it is stated that ABRAHAM, who lived about two thousand years before the Christian era, was rich in cattle, and in silver, and in gold; and on the death of his wife he purchased a field for a burying-place, the payment for which was made with four hundred shekels of silver, which he delivered not in coin, but *by weight, according to the currency of the merchants*. JOSEPH, the great grandson of ABRAHAM, was sold by his brethren to a caravan of Arabian merchants for twenty pieces of silver; and when he was established in Egypt as minister of the king of that country, his brothers brought *silver in their sacks' mouth* to purchase corn during a season of scarcity. Afterwards, when making himself known to his family, JOSEPH presented to his younger brother, BENJAMIN, three hundred pieces of silver. The author of the book of Job, who is certainly a very ancient writer, not only speaks of *the dust of gold*, but says, *Surely there is a vein for the silver, and a place for the gold where they find it*; so that he seems to have been well acquainted with the fact that silver was found in veins, and gold commonly in small particles. The vast amount of the precious metals accumulated by DAVID and SOLOMON has been mentioned in the article on GOLD, and in the first book of Kings it is stated that all the vessels of the house of the forest of Lebanon were of pure gold; *none were of silver, for that metal was nothing accounted of in the days of SOLOMON*, and, in short, *the king made silver to be as stones in Jerusalem*.

The accounts given by the profane writers of antiquity are equally surprising, and some of them altogether incredible. In POLYBIUS, for example, is found a description of Ecbatana, at a period subsequent to the capture of that place by ALEXANDER, in which it is stated that the beams, the roofs, and the pillars which supported the porticos and peristyles of the palace, were all covered with plates, some of silver and some of gold. The tiles, likewise, were all of silver. Though the place had been three times plundered before ANTIOCHUS arrived, there were still remaining in the temple of Ena some pillars eased with gold, and a large quantity of silver tiles, laid together in a heap. CRÆSUS, king of Lydia, who lived about five hundred and forty years before Christ, and whose wealth has become proverbial, is stated by HERODOTUS and DIODORUS to have made presents to the temple of Delphi amounting to four thousand talents of silver and two hundred and seventy talents of gold, or near three millions in value of British money.

The principal sources from which the ancients obtained their gold have been mentioned in the article

on that metal, and probably much of their silver was obtained from the same localities. PLINY speaks of a people named the Dardaneans, who inhabited a country the richest of all India in gold mines, and the Scythians, he says, have the most abundant mines of silver. The chief sources of the wealth of the ancient kings of Egypt were the mines of the neighboring countries of Nubia and Ethiopia, which produced not only copper in abundance, but also gold and silver, before iron was known in Africa. According to XENOPHON, the Athenians worked the silver mines of their own country—Attica—from an unknown age, as well as the gold mines in their foreign possessions in Thrace, and in the island of Thasus. Epirus also had silver mines, which continued to be worked in the time of STRABO; but it appears probable that, for a long time, the only ore that was used was that found near the surface. The Colophonians were the most celebrated among the Greeks for their skill in smelting gold, but none of them were equally expert in smelting silver; for, according to STRABO, their successors were enabled to separate the silver from the residual earths with a profit, although even the latter were much inferior in skill to modern metallurgists.

But the country most productive of the precious metals, and especially of silver, in very remote ages, was the Spanish peninsula, which many authorities assume to have been the Tarshish of the sacred writings, to which a commercial expedition was sent by SOLOMON. It is certain that Spain was visited and colonized by the Phœnicians at a very early period, and that continual intercourse was maintained between the colonists and the mother country, as well as with the future descendants of the same race, the sons of Tyre and Sidon, who founded Carthage. The story of the discovery of the mineral wealth of the country, as related by DIODORUS, resembles many of the fables which in ancient times were dignified with the name of history. He states that the Pyrenean mountains were covered with thick woods, which were set on fire either by the shepherds or by lightning, and continued burning so long that the heat melted the minerals, in consequence of which the silver, with which the soil abounded, ran down into the valleys like a stream of water! He adds, that as the inhabitants were unacquainted with its value, they readily exchanged it with some Phœnician traders, who accidentally visited their shores, for some trifling articles of ornament. The traders loaded their vessels with the precious metal till they could carry no more, and then cut their leaden anchors from the bows, and replaced them with others of silver. These statements are extravagant; but there is no doubt that in ancient times a vast amount of silver was successively extracted from Spain by the Phœnicians, the Carthaginians, and the Romans, and exported to all parts of the world in exchange for merchandise.

Gold, iron, and lead were procured in the South, and some tin in the North of Spain; but the gold was probably of small amount, and silver was the chief mineral wealth of the country. Of this mineral PLINY says it was found in all the Roman provinces, but the best in Spain, and that in a barren soil, even in the

mountains; and wherever one vein was discovered, another was found not far from it. He mentions, as a very singular fact, that the mines begun by HANNIBAL still existed in his time, and retained their original names. One, which was still called Bebullo, from the discoverer, had formerly supplied HANNIBAL with three hundred pounds weight of silver daily. This, he adds, was effected by means of passages under the mountain a mile and a half in length, in which the laborers, standing in water, worked night and day by lamp-light to draw off the water, which at length accumulated to such an extent as to form a large river. JACOB, in his *History of the Precious Metals*—an elaborate work, to which the Editor is chiefly indebted for the facts condensed into this historical notice—states that the situation of the mine mentioned by PLINY is at present well known to have been at Guadalcanal, in the modern province of Cordova, at the foot of the Sierra Morena; and, judging from what has been surveyed of it in more recent times, the water, which was imperfectly drained by the costly subterranean tunnel noticed by PLINY, has long since overflowed the whole interior of the mine; but whether it was exhausted of its treasure and abandoned on that account, or whether it was destroyed by the influx of the water, cannot now be ascertained. It is interesting to remark that HANNIBAL chiefly derived from the silver wealth of Spain the sinews of war, which enabled him to shake to its foundations the Roman empire; and, for many years, he greatly over-worked the mines of that country in his eagerness to accumulate and hoard immense treasures, with a view to the accomplishment of the one great object on which he had set his whole heart.

During several centuries of profound darkness which succeeded the overthrow of the Roman empire, mining operations appear to have been suspended throughout Europe, and the dates at which they were generally resumed are not precisely known. The chief sources of mineral wealth in the middle ages were the Austrian mines, or at least those which existed in countries that are now included within that empire; and, of these, it is considered probable that the mines of Chemnitz and Kremnitz in Hungary were those first worked. FERBER dates the opening of Chemnitz in 745, and that of Kremnitz in 770; but AGRICOLA, who states that they had previously been worked by the Romans, dates their reopening nearly a century earlier. The silver in these mines is chiefly found in lead, in a proportion varying from two to twenty ounces of silver in a hundred pounds of the baser metal. In Bohemia there are celebrated mines of silver at Joachimsthal, in the circle of Saatz, but at what period the workings in them commenced does not appear. In some of these mines the galleries have been carried to the extent of five thousand six hundred fathoms, and some of the shafts are three hundred and fifty fathoms in perpendicular depth. At Altenberg, also, the metals were found in beds of gneiss, in which were mingled felspar and granite; but the mines of Schellgadin are at present the most important. These were also originally worked by the Romans, and the earliest records of their resumption date back to 1378. In the

Tyrol, near Brixen, are silver mines, which, during the excitement in the sixteenth century occasioned by the discovery of the mineral treasures of America, obtained the name of El Dorado. In the year 1523 they produced three thousand eight hundred pounds of silver, but subsequently they decreased in value, and have long been discontinued.

The mines of Saxony, says JACOB, were first discovered in the tenth century, when the whole district in which they are situated was covered with wood and without inhabitants. Some carriers from Halle, on their way to Bohemia, observing metallic substances in the tracks made by the wheels, took them up and sent them to Goslar to be examined, when they were found to consist of lead with a considerable quantity of silver. This led to the establishment of mining operations, which have continued from the year 1163 to the present day. For some years in the fourteenth century the mines of Schneeberg are said to have yielded so large a portion of silver, that the tithes amounted in thirty years to three hundred and twenty-four thousand quintals; but these latter mines have long been exhausted.

The mines in the Hartz forest in Germany, which, at the time of this discovery, formed a portion of Saxony, are now partly in the dominion of Hanover, and partly in that of Brunswick. There are various conflicting opinions respecting the discovery of the mineral wealth of the Hartz. The most probable accounts fix it in the tenth century, and the tradition is that a hunter of the name of Ramm, when engaged in the chase, had fastened his horse to a tree, when the animal, by pawing with his feet, scraped away the soil and thereby discovered some minerals. Specimens of these were sent to the Emperor OTHO, who immediately despatched expert miners to examine the district. The result was that mines were established, which still continue to be worked, and the oldest is named Rammelsberg, from the discoverer. JACOB estimates the whole Hartz, including the dominions of Hanover and Brunswick, with a small part belonging to Prussia, to have yielded, for some years prior to 1830, about sixty ounces of gold, and three hundred thousand ounces of silver annually.

From the times when the rich mines of Spain were last worked by the Romans, they seem to have been greatly neglected. CARDENNE, however, asserts that the mines of gold and silver which existed in that country were a great source of wealth to the Arabs. The mine of Zalamea, to the South of the river Guadiana in Andalusia, appears to have been worked in the middle ages. It is said to have contained silver without any mixture of lead, though near it was another mine yielding only lead; but the most important mines of Spain, and those which have attracted the greatest attention, from the earliest ages down to recent times, are the quicksilver mines at Almaden, and the silver mine at Guadalcanal. Of the latter Mr. BURR observes, that very minute and authentic records were preserved during the period it was worked in the sixteenth century, on account of the government. In these it is stated to have produced four hundred thousand two hundred and twenty-three

mares of silver in the first few years after its discovery, and while worked by the state. After this period it passed into the hands of the Fucars, who are said to have obtained immense treasure from the mine previous to its being abandoned, and filling with water. It is only within the last twenty years, adds the same authority, that Spain has again become a silver-producing country, several very rich mines of that metal having been discovered since the recent revival of mining, which dates back only from 1825. In 1839 the celebrated mines of the Sierra Almagrera in the province of Almeria, were discovered, and they have ever since poured a large amount of silver annually into circulation. In 1843 another great discovery of silver was made—the mines of Hiendelencina in the province of Guadalajara, which have since been very productive; and, passing over recent and minor discoveries, Mr. BURR states that within the last few years the introduction of Mr. PATTISON's desilvering process—a process fully explained in the article LEAD—has been very general in the provinces of Murcia and Almeria. A large quantity of silver is thus annually obtained from the slightly argentiferous lead ores of the Sierra de Gador, and of Cartagena, not formerly extracted, but which now contributes to swell the production of this metal in Spain.

The silver mines of Norway and Sweden were long famous, but have latterly become less productive. The mine of Sahl, or Sala, is said to have been worked five hundred years ago. The silver mines of Kongsberg in Norway were scarcely known before 1623. In some years between 1710 and 1767 they yielded a large profit, but in others they were attended with heavy loss, and have frequently been suspended for long periods.

Although in ancient times Britain was celebrated only for its tin, and yielded but small quantities of the precious metals, yet not only does proof exist that gold was found to some extent, but STRABO states that silver mines were worked in this island, and TACITUS represents AGRICOLA, in his oration before the battle of the Grampian mountains, as reminding his soldiers of the riches in gold and silver which were to reward their valor. It is probable that these riches existed only in the historian's imagination—so far at least as they were to be found in a form available to the metallurgical skill which then existed. In modern times silver has been found in the British islands only in small quantities, except in connection with lead; and before the introduction of Mr. PATTISON's process, the trouble of its separation from that metal more than counter-balanced the profit. There are records, however, of silver mines in Cardiganshire, and also in the county of Tipperary in Ireland, both of which are said to have been worked to some extent during the reign of ELIZABETH. It is stated also that Sir JOHN ERSKINE was a proprietor of silver mines at Alva, near Stirling, which ceased to be worked in 1729, having been carried on for six years previously, under the direction of one PEEK, an Englishman; and in the reign of MARY STUART some silver mines were worked near Linlithgow. The produce must have been very trifling, and the profitable mining of either of the precious metals

was virtually a thing unknown in this country until the introduction of Mr. PATTISON's process rendered it advantageous to extract silver from lead; and as this metal is produced to a greater extent in Great Britain than in any other country in the world, the result is that, by virtue of the process above-mentioned, it is now actually entitled to no mean rank as a silver-producing country. The lead of some of the English mines, especially those of Cornwall, and also of the Isle of Man, contains considerable quantities of silver; and the reader will be surprised to learn that one of the highest authorities on this subject, Mr. ROBERT HUNT, has estimated that in 1852 the United Kingdom furnished no fewer than eight hundred thousand ounces of silver, worth, at five shillings an ounce, about two hundred thousand pounds, obtained from lead alone.

But the greatest impetus given to the supply of silver in what may be termed the modern era, arose from the discovery of America by COLUMBUS in 1492. It is true that up to the invasion of Mexico by CORTÉZ, in 1519, gold alone had been found in America; or if any silver was procured, it seems to have been in small quantity. Thirty or forty years after that event, mines were in full work at Taseo, Zaltepeque, and Paehuea, but the use of mercury was not yet understood. The smelting of the ore was performed in small portable furnaces, or cylindrical tubes of clay, very broad and pierced with a great number of holes. In these the Indians placed layers of silver ore, galena, and charcoal, and a draught was created by the current of air which passed through the holes. Twenty years after the conquest of Mexico by CORTÉZ, PIZARRO achieved that of Peru, and numerous mines yielding both gold and silver were soon opened in that country, but none equal in importance to the celebrated mines of the Cerro de Potosi, which were discovered accidentally in 1545. According to HERRERA, the discovery was made by an Indian hunter, DIEGO HUALCA, who, in pulling up a shrub, observed filaments of pure silver about the roots. On examination the mass was found to be enormous, and a very great part of the population was drawn to the spot and employed in extracting the metal. A city soon sprung up, though in a district of unusual sterility. The mountain was perforated on all sides, and the produce in a few of the first years exceeded anything that had been previously recorded in the mining history of the world.

The sensation created throughout Europe by the news of the discovery of the silver treasures of Potosi, can only be compared to the similar effect produced in recent times by the discovery of the auriferous deposits of California and Australia, which has been fully described in the article GOLD. The wealth of the new El Dorado was, however, grossly exaggerated. From reliable data it has been estimated, that between the year 1557, when the process of amalgamation was introduced, and the year 1578, the annual product of the Potosi mines did not exceed four hundred and forty thousand pounds sterling, which sinks into absolute insignificance compared with the vast amount of treasure now annually exported from California and Australia, without including the newly discovered and still comparatively unexplored deposits on the

banks of the Fraser River. On the whole, the greatest produce of gold and silver, even at that period, was from the Mexican mines, some of the richest of which were already in full activity, although the amount which they yielded was at that time much less than in the course of the two following centuries—the seventeenth and eighteenth—when quicksilver became more abundant, and was more extensively employed in the process of amalgamation. The chief increase of the precious metals between the years 1500 and 1600, was in silver from Mexico, where the production of Zaccatecas, Guanaxuato, and the other mining districts, had then greatly advanced. In the seventeenth century the silver mines of Yauricocha or Pasco, in the northern part of Peru, were first opened, and yielded a large amount of that metal. It is thus that though Potosi, which had at first produced the greatest quantity of silver, had declined, the product of the other parts of Peru so much increased as more than to compensate for that deficiency; and this increase, especially of silver, was greatly facilitated by the extension of the mines of mercury at Huancavelica.

The product of the precious metals from the American mines continued steadily to increase till 1809, when the convulsions commenced which terminated in the separation of the Spanish vice-royalties from the yoke of the mother country, and the erection of Mexico, Peru, and Chili into independent republics. During these troubles, which continued from 1809 to 1821, the produce of the mines greatly decreased, but has since been gradually augmenting.

The aggregate and relative amounts of silver obtained from different parts of the world, will be stated at the end of the article under the head of Statistics.

SOURCES.—As silver is of great use in the arts, not only for purposes of coinage, but also for services of plate for which it is peculiarly adapted, inasmuch as it is seldom attacked in the slightest degree by any of the substances used for food, so it occurs in great abundance in nature, and is largely disseminated both in the native state and alloyed with various other metals, occurring particularly in lead ores, as noticed under the article **LEAD**.

Native Silver is characterized by most of the properties of pure silver, but is always alloyed with a small quantity of other metals. It is generally dull at the surface, but exhibits, on being scratched, the pure white color characteristic of the metal. From its slight impurities, it is also less malleable and ductile than silver perfectly pure. It occurs sometimes crystallized in cubes and octahedrons; sometimes in thin leaves or in dendritical or arborescent shapes, resulting from minute crystals implanted upon each other; frequently also it is found in amorphous masses. It is met with chiefly in the primitive formations, as in granite and gneiss; more rarely in the argillaceous schists and grauwacke of the transition rocks, accompanied by quartz, carbonate and flint of lime, sulphate of barytes, carbonate of iron, galena, *et cetera*. The principal localities in which it occurs native are—Kongsberg in Norway; Schlangenberg in Siberia; Freiberg, Schneeberg and Johanngeorgenstadt in Saxony; Joachimsthal, Przibram, and Ratiborzitz in Bohemia; Schemnitz in

Hungary; Kapnik and Felsobanya in Transylvania; Andreasberg in the Hartz, Allumont in France; and, lastly, Mexico and Peru in America. In some of these localities it has been found occasionally in considerable masses. Thus, at Kongsberg, pieces have been extracted weighing from fifty to six hundred pounds; in America, at the end of the last century, lumps of two hundred to eight hundred pounds were obtained; and on one occasion a block of solid silver was discovered in the mine of Johanngeorgenstadt, which is said to have weighed nine or ten thousand pounds.

SULPHIDE OF SILVER—*Glaserz* or *Silberglanz*, German—contains eighty-five to eighty-seven per cent of metallic silver. It is of a blackish dark-grey color, dull externally, but showing a metallic lustre when cut. It crystallizes in cubes or octahedrons, but is generally met with in the amorphous state. It is slightly malleable, almost as soft as lead, and is easily cut with a knife. It fuses readily in the flame of a blow-pipe, and even in a simple jet of gas, disengaging a slightly sulphurous odor, and ends by being reduced on the charcoal to metallic silver. It is met with in nature almost always combined with other sulphides, as those of copper and lead. This mineral is one of the richest and most abundant ores of silver; it forms a large proportion of that annually produced by the various foreign mines, as those of Saxony, Bohemia, and Hungary, and is particularly abundant in the mines of Guanaxuato and Zaccatecas in Mexico. Its composition, according to KLAPROTH, is—

	From Himmelfurst.	From Joachimsthal.
Silver,	86.50	86.39
Sulphur,	13.50	13.61
	100.00	100.00

RED SILVER.—*Rothgültigerz*, German.—There are three species of this mineral:—1. *The antimonial sulphide of silver*, or a double sulphide of silver and antimony—an ore of a dark-red or reddish-black color, very nearly opaque, has a metallic lustre, and usually crystallizes in hexahedral prisms. Its constituents are—silver, from 56 to 62; antimony, from 16 to 20; sulphur, 11 to 14; and oxygen from 8 to 10. It is met with in almost all silver mines, but principally at Andreasberg in the Hartz, Freiberg in Saxony, Kongsberg in Norway, Schemnitz and Kremnitz in Hungary. 2. *Praistüte*, or the double sulphide of silver and arsenic, which is of a clear red color, transparent, with a brilliant lustre, and contains sixty-four per cent of metallic silver. 3. *Myargyrite*, which differs from the antimonial sulphide only in containing one-third of the proportion of sulphide of silver.

BRITTLE SULPHIDE OF SILVER—*Sprædglasserz*, German—presents two varieties essentially distinct—

1. *Polybasite*, a combination of sulphide of silver, sulphide of copper, and sulphide of antimony or arsenic; has a semi-metallic lustre and an iron-grey color; seen by transmitted light, in thin scales, it presents a blood-red color; it contains 60.5 to 72.25 per cent of silver, and is found chiefly in the Saxon mines, and also in Mexico and Peru. 2. *Brittle Sulphide of Silver*, properly so called—German, *Schwarz-gültigerz*—which is a combination of sulphide of silver with the sulphide of anti-

mony or arsenic; lustre slightly metallic; color iron-grey, and black when reduced to powder; is found associated with the preceding, as also in Hungary, Transylvania, *et cetera*. According to the investigations of ROSE and KLAPROTH, its composition is as follows—

	From Freyberg By Klaproth.	From Schenitz By Rose.
Silver,.....	66.50	68.34
Copper and Arsenic,.....	00.50	0.64
Iron,.....	5.00	0.00
Antimony,.....	10.00	14.60
Sulphur,.....	12.00	16.42
Loss,.....	6.00	—
	100.00	100.00

Grey argentiferous Copper—*weissgültigerz*, German—a combination of sulphides of silver, copper, lead, and antimony; has a semi-metallic lustre, and a color intermediate between that of lead and steel. That which is found in the mines of Freiberg contains thirty to thirty-two per cent. of silver. The *graugültigerz* is a variety of grey copper much poorer in silver than the preceding.

Plumbo-argentiferous sulphide of bismuth—*wismuth-bleierz*, German—is a brittle, leaden-grey mineral; it is a triple sulphide of bismuth, lead, and silver; contains fifteen per cent. of metallic silver. It is found at Schapbach in the Black Forest, but is a rare mineral.

Antimonial Silver—*speissglanz silber*, German—is a semi-metallic substance of a silver-white color, containing about seventy-seven parts of silver and twenty-three of antimony; it is found at Wolfach in the Black Forest, and in some of the Hartz mines, sometimes crystallized in rectangular prisms, but oftener in concrete masses.

Chloride of Silver.—*silberhornerz*, German, horn-silver—is semi-ductile and sufficiently soft to be cut with a knife; color, pearl-grey inclining to blue, and becoming brown in the air; has a vitreous lustre; is usually translucent; crystallizes in cubes. When pure it consists of silver 75.3, chlorine 24.7, and its composition is therefore represented by the formula Ag Cl .

This mineral, says PHILLIPS, which was formerly supposed to be of rare occurrence, constitutes one of the richest and most abundant ores of Chili, where it is frequently associated with native silver, apparently resulting from its decomposition. It also occurs in massive amorphous fragments in connection with sulphide of silver, but still more frequently in small cubical crystals disseminated in the ferruginous rock known in Chili and Peru under the names of *pacos* and *collorados*. Specimens of this mineral, although of comparatively rare occurrence in the European mines, have been obtained from Norway, Siberia, Saxony, the Hartz, and Cornwall.

Iodide of Silver is a rare mineral of a pale lemon-yellow color, with sometimes a tint of green. It was discovered by M. VAUQUELIN in the Mexican mines, but, from its rarity, is of no importance as an ore of silver. It is composed of silver 77.4, iodine 22.6.

Bromide of Silver was discovered by M. BERTHIER in the Mexican minerals, where it has since been found so abundantly in the district of Plataros, near Zaccatecas, that the ores there raised have received the name of *plata verde*, from the green color which it imparts to

them. According to BERTHIER, it is composed of silver 57.70, bromine 12.50.

Native Amalgam, or *argental mercury*, has a very bright silver-white color, and is so soft as to be easily cut with a knife. It occurs both in distinct crystals and in irregular amorphous masses. It crystallizes in the regular octahedron or dodecahedron. This mineral is found in a great many different localities, but the finest specimens have been procured from Moschellandsberg in Bavaria. Its specific gravity is 14.1, and, according to KLAPROTH, it contains thirty-six per cent. of silver and sixty-four of mercury.

Another species of this substance, says PHILLIPS, forms one of the principal sources of silver in the rich mines of Arqueros, in the province of Coquimbo, Chili. From its malleability and general appearance this product was for a long time thought to be metallic silver. According to the analysis of Professor DOMEYKO, of the mining school of Coquimbo, this amalgam consists of silver 86.63, mercury 13.37, from which it appears to be composed of six equivalents of silver united to one of mercury, and its composition may therefore be represented by the formula $\text{Ag}_6 \text{Hg}$.

Argentiferous Galena.—The sulphide of lead, or galena, is almost always associated with a small quantity of silver in the state of sulphide, and this is the source of the silver obtained in the British Islands. It is regarded as extremely rich when it contains 0.005 of silver, and in many cases it may be extracted with advantage when only a tenth part of that proportion is present.

In general, and whatever may be their nature, minerals are regarded as rich which contain 0.005 of metallic silver.

PURE SILVER.—The silver of commerce is never perfectly pure, being always mixed with a certain proportion of copper and traces of other metals. A small quantity may be obtained pure by dissolving a piece of money or of plate in nitric acid, and adding a solution of chloride of sodium; a double decomposition occurs; the silver is thrown down in the form of an insoluble chloride, while the copper and any other metals that may be present remain in solution. One hundred parts of this chloride are, when separated and dried, mixed with seventy parts of chalk and four or five of carbon, and this mixture is introduced into a crucible and raised to a white heat. Carbonic oxide is disengaged, and chloride of calcium and metallic silver remain in the crucible.

To obtain the silver in a state of great purity, the chloride obtained by the double decomposition in the first instance ought to be repeatedly washed by decantation with boiling water, to be certain of dissolving the other metallic chlorides. Instead of chalk, the operation succeeds perfectly by mixing equal parts of carbonate of potassa or soda with three or four per cent. of charcoal in powder. But as the mixture fuses, the disengagement of gas produces, in this case, a tumescence which may project the matter out of the crucible. For this reason GAY-LUSSAC preferred the use of carbonate of lime, with which the reaction may be effected without fusion, reserving the temperature capable of melting the mixture for the time when, the

reaction being finished, no more gas can be disengaged. When the contents subside, the crucible is filled up with more of the mixture; and when the reaction is finished, the temperature is raised to a white heat; the ehloride of calcium and the silver are melted, and the latter forms, on cooling, a button at the bottom of the erucible. The ehloride of caleium, which lies above it, always contains a certain quantity of ehloride of silver; and to separate the silver from the ehloride recourse is had to the humid proecess. The ehloride is first purified by washing, and then subjected to the action of a little sulphuric acid, and a plate of zinc purified by distillation. The reduction is effected rapidly, and the silver forms a grey, spongy, mass, which often floats on the top, because it is penetrated by hydrogen gas proceeding from the deeomposition of the water. By stirring with a glass rod, after withdrawing the zine plate, the hydrogen is separated from the spongy mass, which then falls to the bottom. The liquid is then decanted off, and its place supplied by water and a little sulphuric acid. This new treatment is necessary, for the spongy substance is a combination of silver with zinc, and not pure silver. Accordingly bubbles of hydrogen gas, proceeding from the solution of the zine, are soon found to be disengaged abundantly. When this ceases, the powder is washed by decantation with boiling distilled water till the liquid is no longer rendered turbid by ehloride of barium. In this way the silver is obtained pure, in a state of minute division.

Chemical Properties.—At ordinary temperatures silver is not acted upon by oxygen, but it is tarnished if exposed to an atmosphere containing very minute portions of sulphide of hydrogen, which is always present, to a greater or less extent, in the air of chambers heated by coal fires. When melted, however, in open vessels, it possesses the remarkable property of absorbing about twenty-two times its own bulk of oxygen, which in solidifying it disengages, producing, probably, that kind of metallie vegetation which takes place on the surface of the silver button when suddenly cooled in the eupel. It is not known whether there is chemical combination or merely meehanical absorption in this case; but BARRUEL considers the latter hypothesis by no means probable. The effects of this singular phenomenon, which has been already alluded to in Vol. II., page 284, in eonnection with the refining of gold, are best shown when the mass of metal is considerable, as, for example, about fifty or sixty pounds. They were carefully studied by GAY-LUSSAC and LUCAS, and are altogether so remarkable that a somewhat more minute account of them may not be unacceptable to the reader. After maintaining about the quantity of metal above-mentioned for a long time in a state of fusion, it is left to cool spontaneously, and begins to solidify at the surface. This proecess commenees towards the edges, and advances towards the centre. The crust thus formed soon cracks, and very fluid silver escapes through the fissures, spreading itself over the surface in a thin layer. This first stage of the phenomenon appears due, not to a disengagement of gas, but rather to the expansion which results from a commencement of crystallization. Soon afterwards, as

the cooling proceeds, the gas in escaping begins to raise the solidified crust at several points, and produces a singular formation of miniature volcanic craters, through which a current of oxygen is disengaged, while lava of melted silver stream over their edges. In the middle of each little crater the liquid mass is seen boiling violently. In proportion as the disengagement of oxygen proceeds, the height of these craters increases, in consequence of the solidification of the metal which takes place over their sides; the greater part of them get partially choked up, whilst the gas escapes with a constantly increasing force, dragging along with it drops of melted silver, which it projects to a distance, and producing at each eruption small explosions, which succeed one another at very short intervals. The cones of eruption may ultimately attain a height of one and a half to two inches, with a diameter at the base of two to three inches; and for a quantity of fifty pounds of silver, the total duration of the *rochage*, as the process is termed in France, varies from thirty to forty-five minutes.

This phenomenon does not occur when the silver is alloyed with a small proportion of copper, gold, or lead; even one per cent. of copper prevents the absorption of oxygen on which it depends. That this is the cause of the phenomenon may be demonstrated on a smaller scale by heating to a white red in a crucible a considerable quantity of silver, and projecting upon it a little nitrate of potassa, which, by its decomposition, produces an atmosphere of oxygen. The crucible is then to be covered, and the heat continued for some time, after which the lid is removed and the vessel plunged into a tub of water, placing over it an inverted bell-glass filled with the same liquid; the oxygen which is disengaged is collected in the bell-glass, and may be measured. This experiment, says BARRUEL, is not without danger, for the oxygen may be disengaged all of a sudden, and thus produce a violent explosion.

When silver is subjected to a very high temperature, either by means of a burning lens, the flame of the oxyhydrogen blowpipe, or a powerful voltaic battery, it rapidly volatilizes, and burns with a greenish flame. In a state of fusion it may be crystallized, and in this case it assumes the cubical form.

Silver does not absorb the oxygen of the air when it is fused with the alkalis, and for this reason silver crucibles are used in laboratories for making analyses of silicates by means of the caustic alkalis, which would attack platinum ones. Chlorine, bromine, and iodine combine very well with silver, and of these three bodies iodine is that which has the greatest affinity for it. Of the acids, it is acted on most powerfully by nitric acid, which dissolves it in the cold; concentrated sulphuric acid requires heat to dissolve it. Hydroehloric acid attacks it only with difficulty, by leaving it a long time to digest; however, if the metal is in a very divided state, and the liquid be heated to ebullition, the action even of this acid is pretty rapid.

Silver readily combines with sulphur, and hence the fact already stated—the facility with which it is tarnished by contact with air containing even a very small proportion of sulphide of hydrogen. In this case its discoloration arises from the formation of a brown film of sulphide of silver. To clean articles so tar-

nished, the simplest method is to plunge them for some time into a solution of manganate of potassa—*chameleon mineral*—which is obtained by heating to redness a mixture of equal parts of potassa and binocide of manganese. In this operation the manganate is decomposed, and reacts on the sulphur of the sulphide of silver, which it oxidises and then dissolves. Oxygenated water, if convenient, may also be employed for the same purpose.

METALLURGY OF SILVER.—With reference to their metallurgical treatment, the minerals of silver are divided into four classes:—

1. Argentine ores, properly so called, and worked for the silver alone;
2. Ores of lead and silver;
3. Ores of copper and silver;
4. Ores of lead, copper, and silver.

The separation of silver from its ores is effected either by the method of amalgamation, or by a series of successive smeltings, which concentrate the silver in a certain quantity of lead, and the silver is afterwards separated by cupellation. The first of these processes consists essentially in bringing the silver ores, which have been previously pulverized and subjected to a special preparation, into intimate contact with metallic mercury; the silver is dissolved in the mercury, and the amalgam, being separated from the other matters by washing, is subjected to distillation; a residue is thus obtained. The advantage which this process presents over all others, is its great simplicity; but as any associated metals which may be present, such as copper and lead, are thereby lost, this method is usually employed only for ores which contain an insignificant proportion of these or other foreign metals. In the other processes the product obtained by successive roastings and smeltings is a quantity of *argentiferous lead* or *copper*, from which the silver remains to be separated. In the case of lead it is separated, as already stated, by cupellation; for copper, the mass must first be submitted to eliquation—an operation which consists in melting or *sweating out* the silver from the copper, and then cupelling with lead.

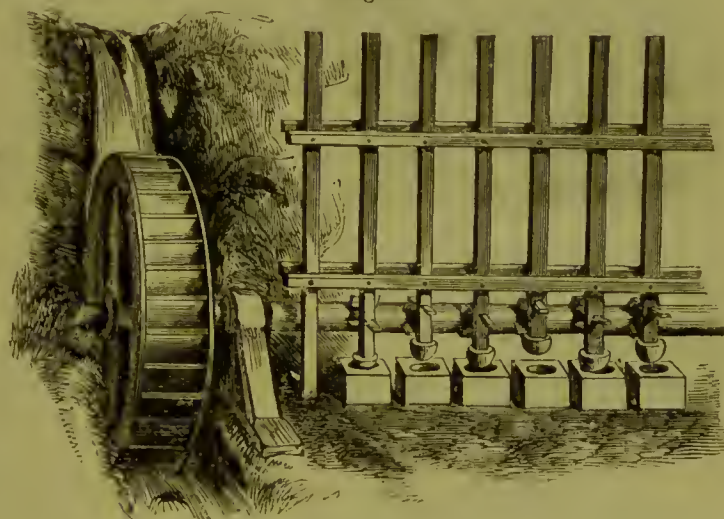
I. ORES WORKED FOR THE SILVER ALONE.—It has been stated that ores of this class, which do not contain an important proportion of other metals, are subjected to a process which consists essentially in forming an amalgam of the silver with mercury, and then subjecting the amalgam to distillation. This is the essential part of the process. Much of its success, however, depends on the manner in which it is conducted, and especially on certain preliminary operations which are required to bring the ore to that state of minute division in which it is most favourably circumstanced for causing the whole of the silver that is contained in it to combine with the mercury. There are two processes by amalgamation, the American or Mexican and the Saxon, which differ considerably from each other in this respect.

American process by amalgamation.—This method, invented in Mexico by BARTHOLOMEO DE MEDINA in

1557, is still practised in that country in all its primitive simplicity; and, perhaps, when the cheapness of labor, the poverty of the ores, the scarcity of fuel, and the deficiency even of water-power are considered, it could not be profitably superseded by any other. It will be found that its principal characteristics depend on these circumstances.

The ore, on being extracted from the mine, is placed in the hands of the *pepenadores*, men and women who break all the larger pieces with hammers, and after rejecting those in which their experience teaches them that no metallic particles are contained, and setting aside those which are very rich to be treated by the smelting process, they subject the rest to a process of crushing and pulverization, with a view to its direct treatment by amalgamation. The ores destined for this treatment are submitted in the first place to the action of the *ingenios* or stamping mills, which are either driven by mules, or, when water-power is at hand, by means of a small breast-wheel—Fig. 485. The long horizontal shaft fixed on the axis of the wheel is armed with five or six cams, placed at diffe-

Fig. 485.



rent situations round the shaft, so as to act in succession on the projecting teeth of the upright pestles or stampers, each of which weighs two hundred pounds, and works in a corresponding oblong mortar of stone or wood. It is estimated that a battery of eight of these stampers, is capable of reducing to powder three thousand five hundred pounds of ore in twenty-four hours.

The powder thus obtained not being sufficiently fine for the purpose of amalgamation, it is transferred from the stamps or *morteros* to be reduced to an impalpable slime or mud in the crushing mills or *arrastres*, represented in Fig. 486, into each of which a little water is introduced. These mills are commonly worked by mules, which turn a vertical shaft armed with two cross-bars. The grinding stones, as well as the sides and bottom of the mill itself, are composed of granite, four blocks of which revolve in each crushing mill, one attached to each of the arms. They are usually placed in a covered shed or gallery, as shown in the figure, which represents the *arrastres* of the *hacienda* or metallurgic works of Salgado, near Guanajuato. These

contain thirty-six dry stampers, also worked by mules, and forty-two crushing mills in which water is used. Each of the latter reduces to a fine impalpable metal-

liferous mud six hundred pounds of powder in twenty-four hours. The mules are changed every six hours. This operation is considered of great importance, for

Fig 486.



the subsequent amalgamation is so much the more complete, and the loss in mercury less considerable, in proportion as the ore is reduced to a more minute state of division.

The ore thus ground into a fine paste is termed

Fig. 487.



lama, and is conveyed into pits of three to six feet in depth, where it is allowed to dry in the sun till it acquires a certain consistence. It is then carried to the *patio* or amalgamation floor—Fig. 487—which is a flat space open to the sky, and surrounded by a stone wall. At Zacatecas the *patio* is rectangular, three hundred and twelve feet in length by two hundred and forty in breadth, and capable of containing twenty-four flat circular heaps of *lama*, each about fifty feet in

diameter and seven inches deep, arranged in four rows. These heaps are termed *tortas*. A small space is usually reserved at one corner for the purpose of performing assays on the ore, with the view of determining beforehand the proportion of mercury that may be necessary to incorporate with each heap.

At Zacatecas the *tortas* are formed in the following manner:—In the first instance a space of the requisite size is marked out and inclosed by a number of rough planks, which are propped in their places by large stones. About one hundred and fifty bushels of crude or impure sea-salt are then introduced into this inclosed space, and over this about six hundred metrical quintals of the *lama* or ore in a state of fine paste. The salt and *lama* are then well mixed by turning with shovels and treading with mules, after which the mixture is left at rest during the remainder of the day. On the morrow, after about an hour's further treading with mules, the *magistral*, or roasted and pulverized copper ore—a mineral containing ten per cent. sulphate of copper, and as much sulphate of iron—is added in greater or less quantity, according to the richness of the argentiferous ore and the season of the year; in summer, for example, and with the richer ores, about seven hundred and fifty pounds to the *torta*, and in winter only half that quantity; for it is stated as a singular fact that in summer the mixture cools and requires more warmth, while in winter it acquires of itself additional heat. The larger proportion is for minerals containing 0.0015 of metallic silver. When the operation proceeds too rapidly, arising from the presence of too much *magistral*, which would occasion

a greater loss in mercury, the remedy is to add a certain quantity of lime, which serves to cool the lama.

When the magistral has been introduced, the treading out is continued for five or six hours by means of six mules. When the whole has been well mixed, the process of amalgamation is commenced by adding a certain quantity of quicksilver, which is sprinkled over the heap by straining it through a bag of coarse cloth. The treading by mules is then continued, and the whole is turned over for some hours with wooden shovels. This operation is repeated for several days, until the amalgamator ascertains by examination that all of the mercury is taken up. He then adds a second and sometimes a third charge, repeating on each occasion the same treatment. When the last charge has been added, the mixture is again thoroughly trodden, and the mass is then removed by the laborers on handbarrows to the *lavaderos*, where the amalgam is separated from the earthy matters by washing.

To judge of the progress of the amalgamation from time to time, the amalgamator uses a small black earthenware basin, flat and round, or somewhat similar in form to that represented in Vol. II., Fig. 221, page 272. In this dish he puts a little of the lama or paste which is under the process of amalgamation, and holding the dish inclined and half-immersed in the water, he gives it a rotatory movement in a plane perpendicular to its axis, so that there is formed in the submerged part of the basin a circular current of water which retains the sand in the centre, while the heavy or metallic grains arrange themselves around the circumference according to their specific gravities, and there the amalgam is observed in small spangles. Usually eight parts of mercury are added for one part by weight of silver contained in the ore. Thus, at Zacatecas, for an ore which is presumed to contain 0.001625 of silver—and this is the average proportion—there is added to the torta, which is estimated to contain about two hundred pounds of silver, on the first occasion nine hundred pounds of mercury; on the second, three hundred pounds; and on the third and last, four hundred and twenty pounds, making a total of one thousand six hundred and twenty pounds of quicksilver. The entire duration of the amalgamation is twelve to fifteen days in summer, and twenty to twenty-five in winter. This is less than a third of the time required at some other Mexican mines, which evidently arises from the small elevation given to the tortas, and the consequent exposure of a large surface to the action of the solar rays.

The next operation is the washing of the amalgamated ore, for the purpose of removing the earthy matters, and of thereby obtaining the amalgam or mixture of silver and mercury in a separate form. This operation is performed in *lavaderos*, or washing vats, which are circular in form, and solidly built in masonry, each about eight feet deep and nine in diameter. A horizontal toothed wheel, mounted on a shaft worked by mules, communicates, through the intervention of another toothed wheel, a movement of rotation to a vertical shaft placed in the middle of the vat, and armed at its lower part with four agitators consisting of cross

beams, from which rise long wooden teeth to the height of five feet. A small stream of water continually flows into the vats from a tank on a higher level. Under the action of the agitators the lighter earthy matter is kept afloat, while the heavier amalgam sinks to the bottom, and from time to time the former is allowed to flow out into a second similar apparatus, where it is subjected to a second washing, and then allowed to run away. An entire torta of amalgamated ore may thus be passed through one vat in twelve hours.

The liquid amalgam obtained in this manner is then strained through a leathern bag, the bottom of which is formed of strong canvass or thick flannel. The uncombined mercury is thus squeezed out, carrying along with it a small quantity of silver, which is not lost, as the same mercury is employed in the next amalgamating operation, while there remains in the bag a mass of semi-solid amalgam, which is submitted to distillation to obtain the silver. For this purpose it is moulded into wedge-shaped masses, each about thirty pounds in weight, which are arranged in a circle in what is called the *burning house*, to the number of eleven, on a solid plate of cast-iron having a hole in its centre. Over this row of wedges several others are built, and the whole pile is covered with a large iron bell called a *capellina*, which is lowered down upon it by means of pulleys, and carefully luted at the bottom to the iron plate with a mixture of ashes, crude salt, and lama. A loose wall of fire-bricks is then built round the capellina, leaving an interval about a foot in width, which is kept filled with burning charcoal all night; and after the heat has been applied about twenty hours the bricks and ashes are removed and the capellina hoisted up. The silver is then found in a solid mass, the mercury having passed off in vapor through a pipe fixed to the opening or hole in the ground plate, by which it is conveyed into a cistern filled with water, and there almost all condensed. The silver, which remains on the plate in solid pieces, is weighed, and is then usually remelted in reverberatory furnaces, and cast into ingots or bars, each about eighty or ninety pounds in weight. Latterly, at some establishments cylindrical retorts of cast-iron have been introduced for distilling the amalgam. The loss in mercury is usually about one and a half per cent. of the weight of silver obtained.

The rationale of the process of amalgamation, as above described, may be explained as follows:—In America the silver exists in the ores, partly in the native state, partly as a chloride, and partly as a simple or multiple sulphide. The copper pyrites which is added reacts on the chloride of sodium employed, producing sulphate of soda and bichloride of copper; the latter acts as an energetic chloridizing agent on the sulphide of silver in the ore, which it changes into chloride of silver, passing at the same time itself into the state of protochloride. The chloride of silver is in its turn reduced by a part of the mercury added, forming with that part protochloride of mercury, and with the other an amalgam of silver. It is the protochloride of mercury so formed that is carried away by the waters in the process of washing, and constitutes almost the whole of the loss in mercury. The

chloride employed serves not only to transform the sulphate of copper into dutochloride, but likewise to dissolve the chloride of silver, and thus to facilitate considerably its reduction by the mercury.

On an average the American ores are very poor, and do not contain more than 0·00150 to 0·00160 of silver. It is their immense quantity, and not their superior richness, that explains the large production of the silver mines of America. The most celebrated are those of Pasco, Cerro de Bambon, Chota, and Huantajaya in Peru; Zaccatecas, Guanaxuato, Valenciana, and Veta-grande in Mexico. Pasco produces annually one hundred thousand to one hundred and fifty thousand pounds of silver; Huantajaya fifty thousand pounds; Zaccatecas three hundred thousand pounds; Guanaxuato two hundred thousand pounds; Valenciana one hundred and fifty thousand pounds. It is estimated that five-sevenths of the silver produced in America is obtained by amalgamation, and only two-sevenths by smelting the ores.

Saxon Process by Amalgamation.—It was only at the end of the last century that the method of treating silver ores by amalgamation was introduced into Europe. Here the circumstances are different to those in Mexico and Peru; fuel is cheaper, mechanical moving power is abundant; manual labor is more expensive; it is therefore important to replace the latter as far as possible by the former two, and this principle will explain the chief points in which the European process differs from the American. These points of difference will appear from the following account of the method by amalgamation, which is practised at the Halsbrücke works, near Freiberg, in Saxony, the most complete establishment of the kind in Europe.

In these works no ores which contain more than seven per cent. of lead, or ore of copper, are submitted to amalgamation, because beyond that point the lead entering into the amalgam would render it very impure, while making the operation itself more difficult, and the copper would be entirely lost. The most usual constituents of the ores are sulphur, silver, antimonial silver, bismuth, sulphides of arsenic, of copper, iron, lead, zinc, *et cetera*, with several earthy minerals. Ores of different qualities are sorted together in such a way that the mixture may contain an average of about four ounces of silver per one hundred pounds of ore. It is necessary, also, that they shall contain a certain proportion of sulphur, to decompose sufficient chloride of sodium in the roasting to cause as much chlorine to be disengaged as shall convert the whole of the silver into a chloride. Accordingly, ores poor in sulphur are mixed with those that are richer, and generally about thirty per cent. of iron pyrites is added. When the whole has been well pulverized in a stamping mill, about one-tenth of its weight of salt is added, and the mixture is then roasted in a reverberatory furnace, the floor of which is elliptical, and is about six feet in length by eight in breadth; the height of the vault in the centre is about eighteen inches. The furnace is charged with three and a half to four hundredweights of the prepared ground ore, which is first dried at a low heat with incessant turning over; the fire is then gradually raised. At first vapor of water is disengaged, then

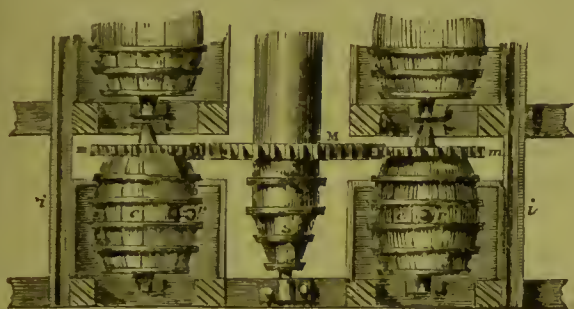
dense white fumes of arsenious acid and oxide of antimony, which deposit themselves in the condensing chambers above; after this the ignition of the iron pyrites becomes obvious by the appearance of a blue flame and a strong odor of sulphurous acid. When this smell has passed away the chlorination is commenced by raising the temperature to a bright red, and maintaining it at that point till no more gas is disengaged; this requires about three-quarters of an hour, so that a charge is passed through the furnace every four hours. During the first part of the operation, or the roasting properly so called, the arsenic and antimony are separated, and the sulphides of iron and copper are converted into a basic sulphate of sesquioxide of iron and subsulphate of copper. These sulphates, in the second part of the process, or the chlorination, react in their turn on the chloride of sodium, producing sulphate of soda, protochlorides of iron and copper, and chlorine, which combines in the nascent state with the silver contained in the ore, thereby converting it into a chloride. Here it is the chloride of iron which principally acts as the chloridizing agent, whereas in the American process it is the chloride of copper. At the Halsbrücke works there are fourteen roasting furnaces, in each of which about five tons of ore are operated upon weekly; and the condensing chambers or soot vaults yield in the aggregate, during the same time, from four to five tons of ore-dust, containing about sixteen pounds, or 0·00125 to 0·00150 of silver. This dust is treated separately in the same manner as the crude or unroasted ore. The fuel of the first fire is pit-coal; of the finishing one fir-wood. Of the former one hundred and fifteen cubic feet, and of the latter two hundred and ninety, are upon an average consumed for every five tons of ore. The service of a roasting furnace requires two workmen per twenty-four hours of work.

The roasted ore is thrown on a grating inclined at an angle of 45°, and having sixteen apertures to the square inch. That which passes through falls on a sieve or riddle about eight feet long by eighteen inches in width; it is inclined at an angle of 6°, and, in the upper part, has eighty apertures to the square inch, but only fifty in the lower. Three degrees of fineness are thus obtained—the *coarse*, which remains on the grating and the riddle; the *fine*, which passes through the upper part of the riddle; and the *middling*, which passes to the lower part. On the average the proportions obtained are twenty-nine parts of fine, one of middling, and one and a half of coarse or large grains. The latter is broken with a hand-hammer; it is then crushed, along with the middling size, under granite millstones, and afterwards subjected to a second roasting with two per cent. of chloride of sodium: but in this case the operation lasts only two hours instead of four as formerly. The fine is ground in a dry state between granite millstones. The top stones or runners make one hundred and twenty to one hundred and forty turns per minute; they are radiated like those of meal mills; the grooves have a depth of about one-fifth of an inch, and require to be dressed or renewed every three or four days. When they are first put up they are about two and a half feet in diameter, with a thick-

ness of about twenty inches; and when this thickness is reduced one-half, they are used for the lower or bed stones. It is estimated that from two to three horsepower is required for each mill. There are in all ten pair of stones, and each of them grinds per hour from one hundred to one hundred and fifty pounds of roasted ore, besides which there remains on the bolter twelve to fifteen per cent. of coarse material, which must be passed a second time between the stones. The service of two pair of stones requires two workmen per twenty-four hours of work.

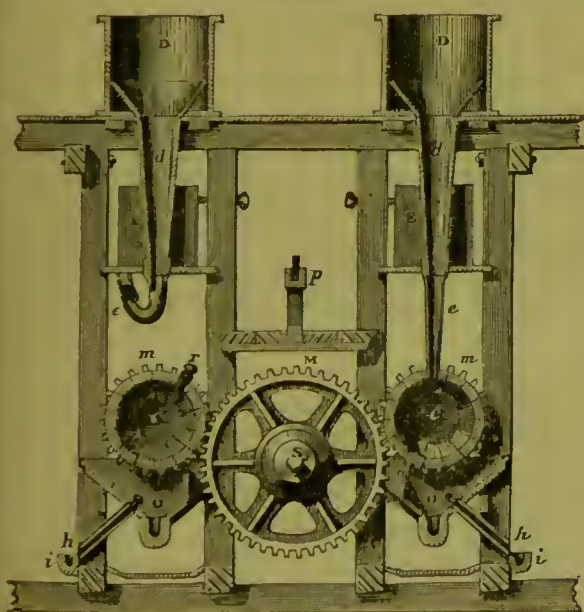
The amalgamation is performed in casks firmly hooped with iron, and each about two feet ten inches

Fig. 488.



long by two feet eight inches in internal diameter. There are twenty of them, arranged in four rows, and turning on horizontal axes. Figs. 488 and 489 will give an idea of this arrangement. Attached to the end of each cask, *c, c*, is a toothed wheel, *m m*, which engages another toothed wheel, *M*, mounted on a shaft,

Fig. 489.



s, which is driven by water-power. Each of the casks has an opening, *r r*, about four inches in diameter, and securely closed by an iron or wooden screw stopple during the amalgamation. The roasted ore is charged into hoppers, *D, D*, which are prolonged downwards by conical tubes, *d, d*, and leather hose, *e e*. The latter are introduced, during the charging of the casks, into the openings, *r r*, and then turned upward as one of them is shown in the figure. Above each cask is a vessel, *E*, for containing the exact amount of water

required for each charge, and these are also fitted with flexible tubes and stopcocks for allowing the water to pass as required. The bearings of the wheels, *m m*, mounted at one end of each of the barrels, and through which they receive their movement from the wheel, *M*, are supported on slides which move to and fro upon the bars, *f*, and the wheels can therefore be disengaged at pleasure. The charge is commenced by introducing into the barrels the water from the vessels, *E*, each of which contains thirty-three gallons, and the whole of this is transferred into the barrels; the roasted ore, to the amount of ten hundred-weights for each, is then introduced, and lastly there is added from eighty to one hundred pounds of iron in pieces about one and a half inch square by three-eighths thick. The stopples are then screwed in, and the casks are thrown into gear, and made to revolve slowly for about an hour and a half at the rate of fourteen to fifteen turns in the minute. During this stage, the chloride of silver dissolved in the alkaline chloride is decomposed by the fragments of iron, producing chloride of iron and metallic silver. It is very important that the roasting should have been carried far enough to decompose all the chloride of copper; for if not so, the latter would be equally reduced by the iron to the metallic state, and would subsequently pass into the amalgam, rendering it very impure. At the end of an hour and a half the barrels are stopped, and five hundred and fifty pounds of mercury introduced into each, by means of pipes connected with the tube *g*, which communicates with a large graduated iron reservoir. The barrels are then put in motion again, with a speed of twenty to twenty-two revolutions per minute, and this is continued for nineteen hours without intermission, except for a short period at the end of every four hours to examine whether the paste has the proper consistence, and to judge of the progress of the operation. The reaction is facilitated by the elevation of temperature which is observable in the contents of the barrels, and which is greater in proportion as the velocity of rotation is more considerable. The higher the temperature the more completely will the residues be exhausted, but the greater will be the loss, in the subsequent washings, of very minutely-divided mercury, which it will then be impossible to recover. There is therefore a proper medium, which has been determined by experience to correspond to about 90°.

The amalgamation being now considered as terminated, the barrels are nearly filled with water, and are made to revolve during two hours with a speed of eight or nine turns per minute, to collect the amalgam. The motion is then stopped, and the process of discharging them is proceeded with. For this purpose the conical lungs, by which they were hermetically sealed during the amalgamation, are removed, and a leathern tube fitted with an iron stopcock is inserted into each aperture; the barrels are then reversed, so that the apertures are turned downward, and the amalgam is made to fall along the sluice, *h*, into the gutter, *i*, which conducts it to a general reservoir. The barrels are then turned up to adjust to them hollow stoppers fitted with wire-grating; and in reversing them again the slimy residue falls into the canal, *o*, which

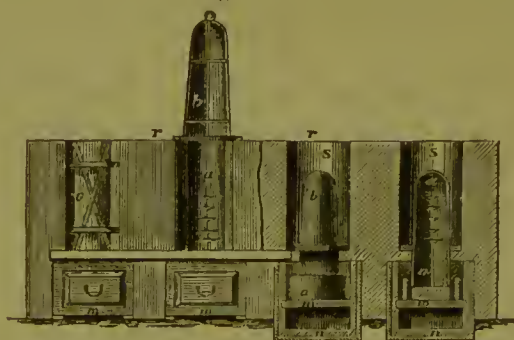
conducts them to the washing vats, while the pieces of iron retained by the grating remain in the barrels. Altogether each operation lasts twenty-four hours. About two pounds of iron are consumed in each barrel at one operation, and about thirty pounds are added every fifteen days.

The amalgam obtained is strained by hand labor through a flannel bag of a conical form; the mercury which passes through contains at the utmost 0·00004 of silver, and is passed back into the amalgamation barrels. The solid amalgam, which remains in the bag, contains, according to KERSTEN'S analysis:—

Mercury, ..	84·20
Silver,	11·00
Copper,	3·50
Antimony, zinc, and lead,	1·00
Sulphur,	traces.
Loss,	0·30
	100·00

Distilling the Amalgam.—The mercury is separated from the silver by distillation. For this purpose the amalgam is placed in flat iron dishes, under a bell-apparatus. Fig. 490 represents the four bells employed at the Halsbrücké establishment; *m, m, m, m* are wooden drawers, sliding in grooves upon the bases *q q*; and each of which contains an open box or basin, *o o*, of cast-iron. In these basins are placed vertical iron rods, *a a*, resembling candelabra, resting upon three

Fig. 490.



feet, and each supporting five flat iron dishes, formed with holes in the centre, whereby they are fitted upon the iron rods, three inches apart, each plate being successively larger than the one above it. About sixty pounds of amalgam are put into each dish, and the whole is covered with a cast-iron bell, *b b*, which is raised and lowered by means of pulleys. When the bells have been let down into their place, the aperture through which they descend is covered with an iron plate, *r*, and the open space, *s s*, which forms the stove, is closed in front with a door, *c*, the edges of which are carefully luted. The boxes, *m*, and basins, *o*, are filled with water, which must be continually renewed through pipes in the sides of the boxes, so that the iron basins may always be kept partially immersed, and as cool as possible. The fuel is then placed in the vacant spaces, *s s*, round the upper part of the bells; and the doors, *c*, being closed and luted, the fire is fed gradually, first with turf and then with charcoal, in such way that it does not attain its maximum heat until about eight hours have elapsed, after which the fire is allowed to decline gradually. The

management of the fire is a point of the greatest importance, and requires the most careful attention; for if the temperature be not raised very cautiously, there is much risk of the bell breaking, and also of a part of the silver being carried over mechanically by the mercury in volatilizing; on the other hand, if the temperature be not sufficiently elevated, there will remain in the silver a greater or less amount of the mercury, which will be completely lost in the refining.

Each distilling operation lasts twelve hours, and the product is about forty-five pounds of plate or *teller* silver from each bell. The teller silver contains only about seventy-five per cent. of fine silver, the remainder being chiefly copper; it is melted in an open iron crucible, and cast into ingots—a process by which most of the impurities are removed, and the ingots contain about eighty per cent. of fine silver.

The earthy residuum of the twenty barrels in which the amalgamation was performed is run into five circular tanks, each about five feet in depth, with a diameter of five feet at the top and three at the bottom; these are filled up with water, and in the side of each there are four orifices, arranged one over the other, at a distance of about five inches from each other. In the middle of each tank is a vertical axis, carrying horizontal arms, which are made to revolve during twenty to twenty-two hours at the rate of twelve to fourteen turns per minute; and while this agitating process is going on, the supernatant liquid containing the lighter earthy impurities, is allowed to flow out, twice by the highest orifice, twice by the second, and once by the third or lowest, taking care to fill up the tanks with water after each partial discharge. The amalgam itself is drawn out by the lowest orifice only once a-week; it is very impure, and after being fused yields an alloy which contains only twenty-five to sixty-five per cent of fine silver. This product might be refined by fusing it with a little saltpetre and borax, but it is sent by preference to the Mint, where it is alloyed with the fine silver which is obtained from the cupellation of lead. The amount of the residues, which are finally rejected as useless, rises to eighty per cent. of the weight of the crude ore, and their contents in fine silver varies from 0·00008 to 0·00016. The waters which proceed from the washing of the amalgamation barrels are purified by deposition, and then concentrated and crystallized in leaden pans: the product is a quantity of impure sulphate of soda, which is februated by a second crystallization. The mother-water, or that portion of the liquid which refuses to crystallize, is concentrated by milk of lime: and the product thus obtained, which is termed in German *dünge saltz*, is employed in the country with much advantage as a manure; it is composed, according to M. LAMPADIUS, of—

Hydrated gypsum,	68·7
Chloride of sodium,	7·4
Carbonate of potassa,	5·3
Hydrates of manganese and iron,	12·9
Clay, sand, and loss,	5·7
	100·0

The total loss in silver varies from five to nine per cent. of the quantity contained in the ore; the loss in

mercury amounts to twenty-five per cent. of the silver obtained, and, from an average of twenty years, it consists of—

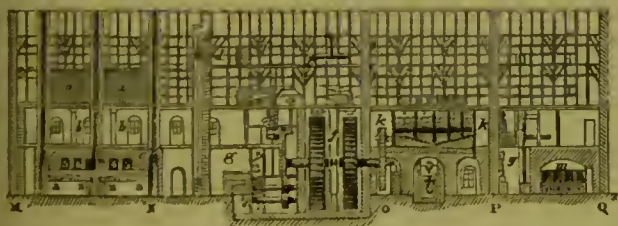
Loss in mercury, which remains in the earthy residues of the amalgamation,	21.78
Loss in the distillation of the amalgam,	2.77
Loss proceeding from the cracking or breaking of the bells,	0.45
	<hr/> 25.00

This small consumption of mercury compared with that of the American process arises from the fact that in the latter the chloride of silver is reduced by the mercury, and the chloride of mercury thus formed passes wholly into the residues, whereas in the Saxon process this reduction is effected by the iron.

Fig. 491 presents a complete view of the amalgamation works at Halsbrücke, shown in longitudinal section; the portion on the left side, indicated by the letters *M N*, is devoted to the roasting and chloridation of the ores; the part embraced between *N* and *O* to the pulverization and sifting of the roasted ore; the third part, *O P*, to the amalgamation, properly so called, and the washing of the residues; and, lastly, the portion *P Q* to the distillation of the amalgam. In these four great divisions the following details will be distinguished:—

1. in division *M N*, *a a* denotes the salt stores; *b b* apartments for mixing the materials; *c c* roasting-furnaces, the flame of which, after passing over the hearths, 2, 3, enters the condensing chambers, 4, 5, and escapes by the chimney, *e*. 2. In compartment *N O*, *g* denotes the grinding mills; *d* the sifting machinery; *f* water-wheels which drive the grinding mills and amalgamation barrels. 3. In division *O P*, *k k* are the amalgamation barrels; *l*, tank for washing

Fig. 491.



the residues. 4. In compartment *P Q*, *m* denotes the furnaces for distilling the amalgam; *q*, store-chamber.

Thus, as the late Dr. URE has observed, from one extremity of the building to the other, the workshops follow in the order of the processes; and the whole, over a length of one hundred and eighty feet, seems to be a natural laboratory, through which the materials pass, as it were, of themselves, from their crude to their refined condition.

II. ORES CONTAINING LEAD AND SILVER.—The treatment of argentiferous lead ores, with a view to the separation of the silver, has been fully described in the article LEAD. It consists in simple cupellation, if the ores are sufficiently rich in silver to warrant the immediate application of that process; and the furnaces used for that purpose, both at Alston Moor in England and at Clausthal in the Hartz, are illustrated in Vol. II., pages 471, 472, where the whole operation is described in sufficient detail. The form of cupel used in England

is exhibited at page 284. The refinery furnace of the works at Friedrichshütte, near Tarnowitz, in Upper

Fig. 492.

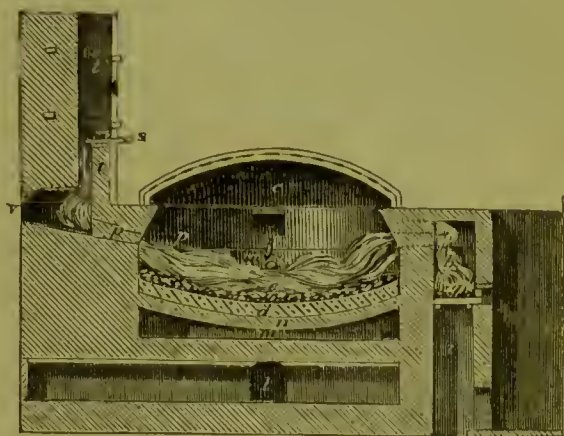
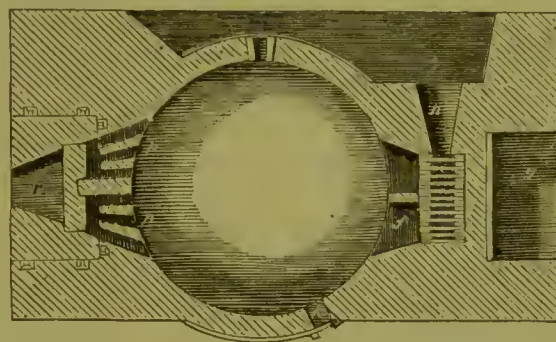


Fig. 493.



Silesia, is shown in section and plan in Figs. 492 and 493; *m* is a foundation of slag or cinders; *n*, a bed of fire-bricks, on which the cupel rests; *d*, the cupel, formed of a mixture of seven parts by weight of marly calcareous dolomite, and one of fire-clay—it is nine feet in diameter, and has a dip of fifteen inches in the middle; *g* is the grate of the furnace; *f*, the fire-bridge; *e*, the dome, or cap, made of iron-plate strengthened with bars, and lined with fire-lute to protect the metal from burning; *h*, the door of the fire-place; *i*, the ash-pit; *l*, the tap-hole; *pp*, flues, divided by partitions, which conduct the flame into the chimney, *tt*; *s*, a valve, or damper, for regulating the draught; *vv*, back valve for admitting air to cool the furnace and brushes to clean the flues, *pp*; *e*, tuyere of copper, which, by means of an iron wedge, may be sloped more or less towards the hearth; *w*, a round piece of iron hung before the eye of the tuyere to break and spread the blast; *k*, the outlet for the litharge. The charge is composed of seventy to eighty metrical quintals of lead. The fusion and removing of the abstrichs occupies six hours, and the formation of the litharges twenty-four to thirty hours—in all thirty to thirty-six hours.

Very poor leads cannot be directly cupelled with profit, because the value of the silver obtained does not defray the expense of the operation. In that case recourse is had to PATTISON'S process, which has also been fully described in the article LEAD, Vol. II., page 473; and after the lead has been enriched by successive crystallizations, it is then fit to be cupelled.

The following table exhibits the effect of PATTISON'S process on one thousand parts of workable lead containing different proportions of silver:—

Workable lead submitted to one crystallization		Rich lead.		Lead middling rich to be recrystallized with the workable lead	Poor lead.		Proportion between the content in silver of the rich lead and that of the poor lead.
Weight	Content in silver.	Weight	Content in silver	Weight	Weight	Content in silver.	
1000	0.001606	136	0.003800	125	739	0.001200	3.17
1000	0.001230	136	0.003203	125	739	0.000862	3.70
1000	0.000862	162	0.002150	125	713	0.000563	3.78
1000	0.000598	169	0.001606	125	706	0.000357	4.49
1000	0.000568	169	0.001454	125	695	0.000341	4.26
1000	0.000341	234	0.000814	125	641	0.000170	4.89
1000	0.000234	250	0.000598	125	625	0.000088	6.79
1000	0.000088	259	0.000218	125	616	0.000033	6.61
1000	0.000030	100	0.000130	125	650	0.000020	6.59

It will be seen that the concentration of the silver by this process is all the more complete, in proportion as the lead subjected to the operation is poorer in that precious metal; hence, it is particularly applicable to the leads of England and Spain, but not to rich leads. Neither can it be applied with advantage to leads which are both poor and impure, because by cupellation the advantage is gained of separating the impurities in the abstrichs, so that litharges are obtained which are commercially valuable in themselves, or which, if subjected to reduction, yield a lead of superior quality.

The silver obtained from the cupelling furnace represented in Figs. 492 and 493, as well as the rich lead concentrated by PATTISON'S process, still requires further purification, and for this purpose it is subjected in both cases to cupellation on a small scale, with a cupel or test made of bone-ash. Figs. 494 and 495

Fig. 494.

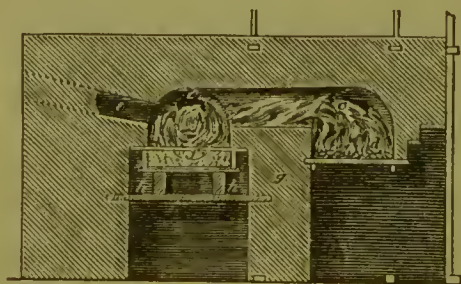
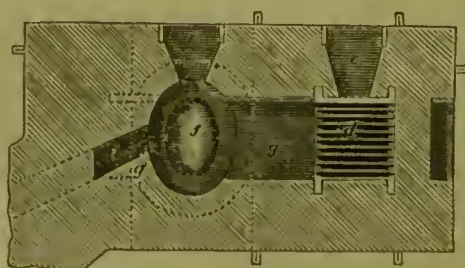


Fig. 495.



represent the refining furnace employed for this purpose at Friedrichshütte; *c* is the fire-door; *d* the grate; *e*, door for charging the rich lead into the cupel; *f*, elliptical cupel of bone-ash, the longer axis of which is about sixteen inches, and the smaller axis ten inches; this cupel is movable, and rests upon two iron bars, *g g*, over which are tiles, *h h*, for adjusting the surface

of the cupel at any desired level; *i*, flue leading to a chimney about eighteen feet in height. About one hundred and ten to one hundred and thirty pounds of rich lead or impure silver constitute one charge of the cupel; and the silver obtained from a previous cupellation on the large scale, yields about ninety-four per cent. of fine silver.

III. ORES OF COPPER AND SILVER.—In smelting argentiferous copper ores, the principal object in view is to obtain the baser metal in that state in which it is termed *black copper*; and when this metal contains less than 0.003 of silver it is deemed sufficiently rich to be submitted to the process of liquation or sweating. This process has been briefly described in the article COPPER, Vol. I., pages 522 and 523; but some additional details will now be necessary. In the first place, the black copper is fused with a certain quantity of poor lead, and the alloy so formed is cast into cakes or discs; these are then submitted to a carefully graduated heat, which causes the lead to melt or sweat out, carrying along with it the greater portion of the silver, which has a stronger affinity for that metal than for the copper. This is the process termed liquation or eliquation. It has been found by experience that, with a view to diminish as much as possible the loss in copper and in lead, the most suitable proportion between the quantities of lead and copper in the prepared discs, is that of eleven parts of the former metal to three of the latter; and that, to extract the silver sufficiently, it is necessary to employ at least four hundred and eighty parts of lead for one part of silver contained in the black copper.

When the black copper is only slightly argentiferous, the poor lead, which has served for a first liquation, is not sufficiently rich to bear advantageously the expenses of cupellation; in that case it is used a second time for extracting the silver from a fresh quantity of black copper. By this means the content of silver in the alloy is nearly doubled, and then it is suitable for being submitted to cupellation.

Lastly, when the black copper is very rich, the process is commenced by subjecting it to a first liquation with workable lead, the products of which are a rich lead for cupelling, and a middling rich black copper; the latter is then submitted to a second liquation with poor lead, which yields cupreous residues very poor in silver, to be treated for rosette copper, and moderately

rich workable lead, which is passed back into the rich liquation process.

The content in silver of the black argentiferous coppers of Mansfeld, which are treated at the liquation works of Hettstœdt, where both the lead and fuel are very high in price, averages 0·00520. The fusing and casting of the liquation discs is performed in a cupola furnace. Each campaign lasts thirty hours, during which time two hundred discs are cast, each weighing about three hundred and eighty pounds, and measuring about two feet in diameter by three inches in thickness. For one thousand pounds of black copper, the proportion of poor lead added is four thousand four hundred pounds. The liquation furnace, with the discs arranged in their place, is represented in Figs. 333 and 334, Vol. I., at the pages above referred to. When the lead, carrying most of the silver along with it, has been melted out, the deformed discs which remain are termed *carcas*. When the heat has been well regulated, all the lead which separates by liquation contains a uniform admixture of copper to the amount of between two and three per cent.

The *carcas*—German, *kienstœcke*—still contain twenty-five per cent. of lead, and, to free them from this, they are subjected to a new liquation, which is termed in French, *ressuage*; German, *darren*. For this purpose the *carcas* are accumulated to the extent of fifteen to twenty thousand pounds weight, in a vaulted chamber, on a series of low parallel walls, between which a wood fire is kept up. In the walls of the chamber are a number of draught holes communicating with a chimney. In front this oven is closed by an iron door lined with clay, but leaving an opening at the bottom for the purpose of introducing the fuel and allowing air to enter. A red heat is kept up during fourteen to fifteen hours; the lead which was still retained by the *carcas* soon begins to run, and becomes in great part oxidised. It falls into the galleries in the middle of the fuel, which have a gentle slope, so that both the lead and its oxide, more or less charged with copper, flow into a basin of water which is placed on the floor of a chamber in front of the oven. The fire is allowed to go out when the scoriæ assume a strong red tinge, which denotes the presence of copper. The residues, which are termed *torrefied carcas*, are then withdrawn, while still at a red heat, and thrown into water to separate the scaly crust of oxide with which they are covered, and which is afterwards separated more completely by means of a pointed hammer. As a general rule, one hundred pounds of *carcas* yield sixty to eighty pounds of torrefied *carcas*, and twenty-five to forty of scoriæ and oxidised debris.

The torrefied *carcas* are refined for rosette copper; they still contain ten per cent. of lead, and yield seventy to seventy-five per cent. of rosette copper.

The scoriæ and refuse of all the preceding operations are fused with the litharges and the residues from the cupellation of the workable lead obtained in the process of liquation; the product is a cupreous lead, which is cast into cakes or discs, and these in their turn are subjected to the series of operations which have just been described. The lead proceeding from the new liquation is, however, poor in silver, and is therefore enriched

by using it for the liquation of the black copper before passing it into the cupel.

In this series of operations, there is lost about ten to twelve per cent. of the lead employed, that is to say, forty to fifty per cent. of the weight of the black copper, or at least sixty to eighty pounds for every pound of cupel silver obtained. The loss in silver usually exceeds twenty-five per cent., regarding that silver as lost which remains in the copper. The loss in copper is five to six per cent. The *carcas* are very difficult to refine, and never yield copper of the first quality.

These results show how imperfect is this method; and hence, in the great metallurgical centres, the method now preferred is to separate the silver from the copper, either by the amalgamation of the matts or by that of the black copper. These operations are effected in a manner analogous to the Saxon amalgamation process, which has been already described, so that it will be only necessary to indicate briefly the special circumstances resulting from the nature of the materials submitted to the operation.

The amalgamation of the argentiferous black copper is practised at Schmöllnitz in Hungary; it contains 0·0040 of silver. The principal difficulty to be overcome is the pulverization of the black copper: to effect this, it is heated to redness on the sole of a reverberatory furnace, and at this temperature it is placed under the pestles of a stamping machine. The matter thus crushed and broken is passed through a sieve; the finer portion is ground to a flour under iron mill-stones, the coarse is reheated and passed again under the stampers. The reduction of the chloride of silver is performed by means of copper balls, so as not to precipitate the copper from the chloride and thus render the amalgam impure, but then the loss in mercury is considerable; in certain cases it would be advantageous to saturate the liquor with lime, and to replace the copper balls by iron, which would diminish the loss in mercury. The residues of the amalgamation are remelted for black copper; their content in silver does not exceed 0·00008, and the loss in that metal is only five per cent.; the loss in mercury is 2·5 lbs per thousand lbs of black copper, or from 0·30 to 0·35 of the weight of the silver. The expenses of amalgamation do not rise to one-fourth part of those attending liquation, and the copper obtained from the smelting of the residues is of superior quality.

The amalgamation of the argentiferous matts of copper is practised at Mansfeld. The matt subjected to amalgamation at that establishment contains about fifty per cent. of copper, and 0·0025 of silver. After pulverizing the matt, it is submitted in a reverberatory furnace to a preparatory roasting, to expel the excess of sulphur; it is afterwards reduced to a thin paste with a dilute solution of sea-salt and twelve per cent. of slacked lime, which serves to saturate the sulphuric acid. The paste thus obtained is dried, ground, then roasted a second time; this is, properly speaking, the chloridation. The reduction of the chloride of silver is effected by means of iron. The residues of amalgamation are mixed, still in a moist state, with twelve to thirteen per cent. of clay, and moulded into small bricks, which are dried in a kiln, and reduced in a

furnace to black copper by adding, to form the smelting bed, twelve to thirteen per cent. of quartz, 1·5 to 2·5 per cent. of fluor spar, and thirty-two to forty per cent. of the slag from the smelting of the crude ore. The loss is eleven to twelve per cent. of the silver contained in the matts, about three-fourths of this amount remaining in the black copper, which contains 0·00046; the loss in mercury is 0·8 of a pound per thousand pounds of matt, or 1·6 pounds per thousand pounds of black copper, that is to say, about 0·35 of the weight of the silver extracted. The loss in copper is less than by liquation, and the metal is of excellent quality.

Instead of employing the different processes which have just been described, the ores of argentiferous copper might be treated in the humid way, in a manner analogous to that which is practised at Linz on the banks of the Rhiue, and at Stadtberg in Westphalia, for the treatment of carbonated copper ores too poor to be treated by the ordinary processes. This method consists in treating these ores with sulphuric acid. It is impossible to submit to the direct action of this acid either calcareous or pyritous ores—the former, because a sulphate of lime would be formed which would cover or surround the copper with a paste, so as to be acted upon with difficulty; the latter, because it would scarcely dissolve in the acid. It would be necessary therefore, in these cases, to separate the gangues by smelting the crude ores, which would give them in the form of matts; and these might be roasted with a small quantity of saltpetre in furnaces, or retorts embedded in masonry, and supplied with an artificial blast. A little small wood would be sufficient to commence the heating, as the combustion of the sulphur would afterwards develop the heat necessary for the roasting. The gases proceeding from the retorts should be made to arrive, along with a current of steam produced by a separate boiler, under and around cases filled with roasted and pulverized matts; by the reaction of the steam and the gases from the retorts, sulphuric acid would be formed, which would dissolve the roasted matts; the latter might be exposed beforehand, in heaps, to the simultaneous action of the atmospheric agents and water, to transform the undecomposed sulphides into soluble sulphates, which might be removed by washing. In like manner, if the roasting of the matts did not furnish a sufficient quantity of sulphuric acid, an additional quantity might be procured by subjecting iron pyrites to the same process. A liquor would thus be obtained, containing the iron, copper, and silver of the matts; and of these the silver might be precipitated at once by metallic copper, then the copper by iron. It might be desirable, for the purpose of diminishing the consumption of copper, to almost neutralize the liquor in the first place by means of lime, and then to separate the sulphate of lime by decantation, which would be attended with no other inconvenience than impairing a little the purity of the precipitates. The silver precipitate might be purified by fusing it with a little nitre and borax; the copper could be refined for rosette copper; and lastly, the sulphate of iron, or green vitriol, might be crystallized for the market, or if dried and then slightly torrefied, it might be used for the manufacture of fuming sulphuric acid.

As regards the argentiferous black copper, it might be dissolved directly in the sulphuric acid, and the silver afterwards precipitated by metallic copper, as is practised in the mints.

IV. ORES OF LEAD, COPPER, AND SILVER.—The treatment of these ores is perhaps the most complex metallurgic operation that exists, and therefore it will be necessary to enter into some detail on the subject. Ores containing lead, copper, and silver, are divided into two great classes, according as the lead or the copper predominates. In the former case they are treated as lead ores; and, besides the workable lead, matts are obtained containing silver, copper, and lead, which are subjected to repeated fusions with substances containing more lead. Each fusion gives workable lead, which is cupelled, and the last matts are melted by themselves for black copper, which is afterwards submitted to liquation or amalgamation, to separate the silver which it still contains.

The ores which contain only a small quantity of lead are carefully assorted, and divided into at least two classes, the rich and the poor ores. The latter, according to their nature, are submitted to a *crude smelting*, with or without the addition of pyrites either crude or partially roasted, serving in the latter case as a flux, or using other fluxes if necessary, exactly as in the treatment of copper ores. The earthy gangues are thus separated, and poor matts are obtained, which are roasted once or oftener, and are then concentrated by fusion along with additional ores of the same richness. The products of this operation are *scoriae* which are passed back into the crude smelting, and *rich matts*. These matts, after several roastings, are fused with plumbiferous substances and ores rich in silver, especially such as contain lead. The products are workable lead, which is cupelled, and matts which are subjected to a new fusion with plumbiferous matters; lastly, cupreous matts are obtained, yielding argentiferous black copper, which is treated in the manner already described. The fusion of the matts along with lead should be performed at a lower temperature than the crude smelting, in order to diminish as much as possible the loss in lead; this is the process followed at Freiberg in Saxony.

Where substances containing lead are rare or difficult to procure, the fusion of the matts with that metal is replaced by a *fusion of concentration*, and the silver is separated from the new matts by *imbibition*. For this purpose the poor lead is melted separately a little before the tapping of the matt, and is stirred with a fire-iron at the instant when the matts flow into the crucible; the lead then decomposes a part of the sulphide of silver, and passes into the matt, while the reduced silver combines with the rest of the lead and produces workable lead. If this workable lead be not sufficiently rich for cupellation, it serves anew for what is called a *rich imbibition*; this process constitutes the old Hungarian method. The new matt is treated over again in the same manner, and finally cupreous matts are obtained, which are fused by themselves, and yield argentiferous black copper.

Fig. 496 exhibits in plan, and Fig. 497 in vertical section, following the line A B, the Frankenscharn

works, near Clausthal in the Harz, for the treatment of argentiferous and cupreous galenas; *a, b, c, d,*

Fig. 496.



e, f, g, denote furnaces for smelting the ores; *h,* low furnaces like the English slag-hearths for working the last matts; *k,* slag-hearths for reducing the litharge; *m,* the liquation area; *n, p,* cupellation furnaces; *xy,* a floor on which the materials for charging the furnaces

Fig. 497.



are deposited and prepared; *c,* the stamping apparatus; *d,* stream of water which impels the machinery.

Eight parts of ore in the rough state, as taken from the mine, yield one part of schlich, fit for smelting; the content of the schlich in lead is sixty to seventy per cent.; the gangue is quartzose and argillaceous. From ten to twelve thousand pounds of schlich are smelted every twenty-four hours. The furnace is attended by relays of three workmen, and a campaign lasts nine or ten weeks. The products are workable lead, which is cupelled, and matts which contain 0.001 of silver and 0.34 to 0.40 of lead. The last matts obtained are roasted several times, and are then smelted, yielding argentiferous black copper, which is submitted to liquation.

COMBINATIONS OF SILVER.—There are three oxides of silver—a suboxide, a protoxide, and a binoxide. Of these the protoxide alone forms permanent and definite saline combinations.

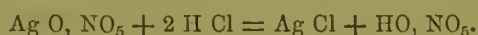
The *Suboxide of Silver*— Ag_2O —was first obtained by FARADAY, by exposing an ammoniacal solution of the protoxide to the action of air. It separates in the form of a black film.

The *Protoxide of Silver*— Ag O —is obtained by adding solution of caustic potassa, or lime, or baryta-water, to the solution of nitrate of silver. The precipitate, when washed, is of a brownish-grey color, anhydrous, tasteless, but soluble, according to GRAHAM, to a small extent in pure water, free from saline matter, and has, when in solution, an alkaline reaction. It is completely reduced to the metallic state by the action of a red heat, or even by the prolonged action of the solar light. In the latter case, however, the black powder which results is possibly the suboxide. By digesting it with caustic ammonia it forms an extremely detonating compound, known as *fulminating silver*, and which, according to GAY-LUSSAC and SERULLAS, is probably an azotide of

silver. This compound, which must not be confounded with the *fulminate of silver*—to be described presently—has hitherto received no application, on account of the extreme danger which attends its preparation and management. It sometimes explodes even while still wet, and should, therefore, be prepared only in small quantities, and handled with the greatest possible caution.

Peroxide of Silver— Ag O_2 —was obtained by RITTER by electrifying a weak solution of silver. It deposits in acicular crystals at the positive pole, but is readily converted into the protoxide, and is of no use in the arts.

Chloride of Silver—*horn-silver*— Ag Cl —is procured by adding a solution of chlorine, of hydrochloric acid, or of chloride of sodium, to nitrate of silver, or to any of the soluble salts of silver, with the exception of the hyposulphite. Thus—



It falls in the form of a curdy precipitate of a white color, but which, by exposure to light, becomes purplish-brown, and ultimately black. In sunshine the change is extremely rapid, more especially if any organic matter be present. It is perfectly insoluble in water, so that the minutest portion of hydrochloric acid, or of a chloride in solution, may be detected by adding to the liquid a drop or two of nitrate of silver. It is sparingly dissolved by concentrated hydrochloric acid, and thrown down upon dilution. It is insoluble in nitric acid and in cold sulphuric acid; but, when boiled in sulphuric acid, it is slowly decomposed. When dry chloride of silver is heated to dull redness in a silver crucible, it fuses, and on cooling concretes into a grey semitransparent substance, which is known as *horn silver*, or *luna cornea*. The presence of moisture is necessary to the blackening effect of light upon the chloride, as when dried in the dark and subsequently exposed to light under an inverted glass over sulphuric acid, no discoloration is produced.

Iodide of Silver— Ag I —is precipitated upon adding hydriodic acid, or a soluble iodide, to a solution of nitrate of silver. It is of a dingy yellow color, insoluble in water, and decomposed when heated with potassa. Like the chloride, it is discolored by light, and hence its use in DAGUERRE's photographic process—the plate of silvered copper intended to receive the image in the camera being prepared by exposing it in a box containing iodine. The iodide is distinguished from the chloride, not only by its yellow color, but also by its being insoluble in ammonia, which constitutes its special characteristic.

Bromide of Silver— Ag Br —is an insoluble yellowish substance, formed in the same manner as the iodide, and having analogous properties.

Nitrate of Silver— Ag O NO_5 —constitutes the most important salt of this metal. It is obtained by dissolving silver in nitric acid diluted with three parts of water; nitric oxide is disengaged, and if the silver contain copper, the solution will have a bluish tinge; if gold, that metal will remain undissolved in the form of a black powder. The solution of nitrate of silver should be perfectly clear and colorless. It is caustic, and tinges

animal substances of a deep yellow, which, by exposure to light, becomes a deep purple or black stain. It is the essential ingredient in many of the washes employed for dyeing the hair, and in the composition of the so-called *indelible* inks for marking linen; but in point of fact, cyanide of potassium will remove the black stain produced by any of the preparations of silver. The crystals are colorless, transparent, anhydrous tables, soluble in an equal weight of cold, and in half their weight of boiling water. Alcohol also dissolves about one-fourth of its weight of this salt at its boiling point, but deposits nearly the whole as it cools. When heated in a silver crucible, the nitrate fuses into a grey mass, and, if cast into small cylinders, forms the *lapis infernalis* or *lunar caustic* of the surgeons. Ivory, marble, and several other bodies may be stained black, or even silvered, by soaking them in a solution of nitrate of silver, and fully exposing them to the action of the sun's rays. A plate of copper, introduced into a solution of this salt, occasions a brilliant precipitation of crystalline silver, and the copper is oxidised and dissolved by the acid. The introduction of mercury into the solution causes a beautiful crystalline deposit of silver, known as the *arbor Diane*. To obtain this crystallization in its most perfect state, the solution should contain a little mercury; and the mercury put into it should be already combined with one-sixth its weight of silver.

Several recipes for indelible or marking inks, formed with nitrate of silver, are given in Vol. II., page 381.

Fulminate of Silver— $2 \text{ Ag O, Cy}_2 \text{ O}_2$.—This curious and dangerous compound is prepared as follows:—One hundred grains of fused and finely-powdered nitrate of silver are added to an ounce of warm alcohol, and the mixture stirred in a sufficiently large glass basin. An ounce of fuming nitric acid is then added, and presently a violent effervescence ensues, and a powder falls. As soon as this appears white, cold water is added, and the powder is immediately to be collected upon a filter, washed, and carefully dried at a temperature of 100° . In collecting and handling this powder, the utmost caution is requisite. It should be made in small quantities only, and touched with nothing hard; for it has sometimes exploded upon the contact of a glass rod even under water. The feather of a common quill serves to collect it; and it should be kept in a wide-mouthed vessel covered by paper, and by no means in a stoppered or even a corked phial, as serious accidents have arisen from its unexpected explosion. In short, one cannot be too careful in meddling with it, and its use for fulminating balls and other purposes of amusement is highly dangerous. It detonates in the quantity of a grain, or even half a grain, with great violence, when heated or touched by any hard body. The nature of this substance has been investigated by LIEBIG and GAY-LUSSAC, who have shown that it is a compound of two equivalents of oxide of silver with one of fulminic acid.—*Brande*.

Sulphide of Silver— Ag S —may be obtained by heating finely-divided silver, or plates of silver, with sulphur. It is a grey crystallizable compound, considerably more fusible and much softer than silver. It is the presence generally of sulphide of hydrogen which occasions the

tarnish upon silver, and which, though only superficial, is a great obstacle to many applications that might otherwise be made of this valuable metal.

Sulphate of Silver— Ag O, SO_3 —is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver with its weight of sulphuric acid. It forms a white saline mass, easily fusible. Upon the large scale, small portions of gold may be most economically separated from large quantities of silver, by heating the finely-granulated alloy in sulphuric acid. The gold remains in the form of a black powder, and the sulphate of silver may be decomposed by the action of metallic copper. The silver is precipitated in a pulverulent state, and, with a little borax or other vitrifiable flux, is fused, and cast into ingots. The sulphate of copper is obtained in the crystallized state by evaporating the residuary liquid.

Hyposulphite of Silver— $\text{Ag O, S}_2 \text{ O}_2$ —is formed by digesting carbonate of silver in hyposulphuric acid. It crystallizes in permanent prismatic crystals, soluble in two parts of cold water. Hyposulphite of silver is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda. A white cloud is at first produced, which redissolves on agitation. On adding more of the precipitant, the cloud reappears, and aggregates into a grey precipitate, which is the hyposulphite. The solubility of argentine compounds in hyposulphites has led to an important application of the latter in photography, for the purpose of fixing the designs by the removal of all adhering or unchanged salt of silver.

Carbonate of Silver is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light, and is easily decomposed by heat. Carbonate of ammonia only throws down a portion of the nitrate, and forms a triple *ammonio-carbonate* of silver.

The other salts of silver are of too little importance to call for special notice.

ALLOYS OF SILVER.—Silver unites difficultly with iron. Upon fusing silver with that metal, the alloy separates into silver retaining about one-thirtieth of iron, and iron retaining about one-eightieth of silver. The latter has a peculiar hard and crystalline texture.

When silver and steel are fused together, an alloy is formed which appears perfect while in fusion, but globules of silver exude from it in cooling, which shews the weak affinity of the metals. At a very high temperature the greater part of the silver volatilizes; but a portion, equal to about one in five hundred, remains, constituting a perfect alloy known as *silver-steel*, and which is admirably adapted to the formation of cutting instruments.

Lead and silver form a very brittle dull-colored alloy, from which the lead is easily separated by cupellation. When fused lead, containing silver, is suffered to cool slowly, the lead which first concretes forms granular crystals, and is nearly pure, while almost the whole of the silver is contained in the liquid portion. The separation of the two metals in this way constitutes PATTISON'S process.

With zinc silver readily combines, producing a brittle bluish-white granular alloy. When a mixture of eleven

of zinc and one of silver is highly heated in an open crucible, it burns, and the whole of the silver is sublimed with the oxide of zinc.

With *tin* silver forms a white, hard, brittle alloy. *Antimony* also forms a brittle white alloy, the density of which exceeds the mean of its components. The greater part of the antimony volatilizes during protracted fusion; and the whole may be separated in the form of oxide by roasting.

Bismuth and silver may be combined by fusion. The alloy is brittle, yellow-white, and lamellar, exceeding in density the mean of the components. The density of an alloy of equal weights of bismuth and silver is 10·7.

Arsenic, fused with silver, forms an alloy composed of 100 silver and 16 arsenic. It is grey, brittle, granular, and by long fusion great part of the arsenic volatilizes. It may be entirely got rid of by roasting.

With *mercury* silver readily amalgamates. When red-hot silver is thrown into heated mercury, it dissolves; and when eight parts of mercury and one of silver are thus combined, a granular crystalline soft amalgam is obtained, the density of which exceeds the mean. When a solution of this amalgam in liquid mercury is squeezed through chamois leather, the excess of mercury, carrying along with it only a small portion of silver, goes through, and the solid amalgam is left behind.

Standard Silver.—The most important alloy of silver is that which it forms with copper. On account of its softness, silver is seldom employed in the pure state; by the addition of a small proportion of copper, it is rendered harder and more sonorous, while the color of the metal is scarcely impaired. A mixture of seven parts of silver and one of copper still retains a decided white color, although of a less pure tint than that exhibited by virgin silver.

The alloy of silver with copper constitutes plate and coin; the proportions are fixed by the legislature of the country in which the mixture is worked. In this country the same alloy is employed both for the purposes of the mint and the uses of the silversmith; it is composed of 11·1 of silver, and 0·9 of copper, and this mixture is known by the name of *standard silver*. A pound troy, therefore, of the standard silver of this country consists of eleven oz., two dwts. pure silver, and eighteen dwts. of copper. Its density is 10·3; its calculated density, according to the mean of the components, 10·5; so that the metals dilate a little on combining.

To prevent fraud, all silver vessels are required to be stamped by the Goldsmiths' Company, who are empowered by government to search all silversmiths' shops, and seize all articles which have not been impressed with the Hall mark of the company. For the assay of the articles, and the impression of the company's stamp, attesting its quality as standard silver, one shilling and sixpence per ounce on the weight of the object is charged. Of this amount the larger proportion is paid over to the government in the form of a tax, whilst a small sum is retained as a compensation for the trouble incurred in making the assay.

In France three different standards are employed.

The alloy used for the silver currency of the country is composed of nine parts of silver, and one of copper; for plate, a mixture of 9·5 parts of silver to 0·5 of copper is employed, whilst for small articles of silver used for ornaments, an alloy of eight parts of silver to two of copper is allowed.—*Phillips*.

The silver coins of the ancients and many Oriental silver coins are nearly pure; they only contain traces of copper and of gold.

When silver alloyed by copper, such as standard silver, is exposed to a red heat in the air, it becomes black from the formation of a superficial film of oxide of copper. This may be removed by immersion in hot diluted sulphuric acid, and a film of pure silver then remains, of a beautiful whiteness; this is called *blanched*, or *dead silver*. It is usual to employ this process in order to improve the color of objects formed of alloyed silver; the article, when heated nearly to redness, is plunged, while still hot, into water acidulated either with nitric or sulphuric acid; the external oxide of copper is thus entirely removed; and the matted appearance of the pure silver, which now forms the surface, soon gives place to a bright polish by rubbing with a burnisher. The blanks for coin are treated in this way before they are struck; whence the whiteness of new coin, and the darker appearance of the projecting portions occasioned by wear, in consequence of the alloy being uncovered. Articles of plate are often deadened or matted by boiling in bisulphate of potassa, which acts in the same way as the dilute sulphuric or nitric acid.

Silver Solder consists of—

Silver,	667
Copper,	233
Zinc,	100

SILVERING.—Almost all kinds of silvering are now usually performed by electro-chemical deposition, and for full details of the process, the reader is referred to the article *ELECTRO-METALLURGY*, Vol. I., page 800, *et sequitur*. When the term *silvering* is applied to mirrors, it generally means the application of a compound of tin and quicksilver, so that, in that sense, the word is misapplied; but, by Mr. DRAYTON's process, described Vol. II., page 227, a coating of actual silver is deposited upon the plate of glass, and in that case, therefore, the term is strictly applicable.

Silver is hammered out into thin leaves in the same manner as gold; and the account of the process given in the article on that metal, Vol. II., page 288, will therefore suffice for both. When silver-leaf is to be applied to the surfaces of bodies, the methods prescribed for gold-leaf, Vol. II., page 290, are also generally suitable. Among the metals, copper or brass are those on which the silverer most commonly operates, and frequently the white alloy of nickel. Iron is seldom silvered, but the process is essentially the same. The principal steps of the operation are summarily described by Dr. URE as follows:—

1. The *smoothing down* the sharp edges, and polishing the surface of the copper, or other metal, to be silvered.
2. The *annealing*, or making the piece to be silvered

red-hot, and then plunging it in very dilute nitric acid, till it be bright and clean.

3. *Pumicing*, or clearing up the surface with pumice-stone and water.

4. The *warming* to such a degree merely as, when it touches water, it may make a hissing sound; in which state it is dipped in very weak aquafortis, whereby it acquires minute insensible asperities, sufficient to retain the silver leaves that are to be applied.

5. The *hatching*.—When these small asperities are inadequate for giving due solidity to the silvering, the plane surfaces must be hatched all over with a graving tool; but the chased surfaces need not be touched.

7. The *charging*, the workman's term for silvering.—This operation consists in placing the silver leaves on the heated piece, and fixing them to its surface by burnishers of steel, of various forms. The workman begins by applying the leaves double. Should any part darken in the heating, it must be cleared up by the scratch-brush.

The silverer always works two pieces at once, so that he may heat the one, while burnishing the other. After applying two silver leaves, he must heat up the piece to the same degree as at first, and he then fixes on with the burnisher four additional leaves of silver; and he goes on *charging* in the same way four or six leaves at a time, till he has applied, one over another, thirty, forty, fifty, or sixty leaves, according to the desired solidity of the silvering. He then burnishes down with great pressure and address, till he has given the surface a uniform silvery aspect.

Silvering by the precipitated Chloride of Silver.—The white curd obtained by adding a solution of common salt to one of nitrate of silver, is to be well washed and dried. One part of this powder is to be mixed with three parts of good pearlash, one of washed whiting, and one and a half of sea-salt. After clearing the surface of the brass, it is to be rubbed with a bit of soft leather, or cork moistened with water, and dipped in the above powder. After the silvering, it should be thoroughly washed with water, dried, and immediately varnished. Some use a mixture of one part of the silver precipitate with ten of cream of tartar, and this mixture also answers very well. Others give a coating of silver by applying with friction, in the moistened state, a mixture of one part of silver-powder precipitated by copper, two parts of cream of tartar, and as much common salt. The piece must be immediately washed in tepid water, very faintly alkalinized; then in slightly warm pure water; and, finally, wiped dry before the fire.

The inferior kinds of coated buttons get their silver coating in the following way:—Two ounces of chloride of silver are mixed up with one ounce of corrosive sublimate, three pounds of common salt, and three pounds of sulphate of zinc with water, into a paste. The buttons being cleaned are smeared over with that mixture, and exposed to a moderate degree of heat, which is eventually raised nearly to redness, so as to expel the mercury from the amalgam, formed by the reaction of the horn-silver and the corrosive sublimate. The horn-silver thus acquires a silvery surface, which is brightened by clearing and burnishing.—*Ure.*

ESTIMATION OF SILVER.—The behavior of various reagents with solutions of silver is given in a tabular form in the article on GOLD, Vol. II., page 269, to which the reader is referred. In general, the *soluble* salts of silver are recognized by furnishing a white precipitate with hydrochloric acid and the soluble chlorides, which blackens by exposure to light, and which is readily soluble in ammonia; and by affording metallic silver upon the immersion of a plate of copper. The *insoluble in water* are mostly soluble in ammonia, and when heated on charcoal before the blow-pipe, they afford a globule of silver. A yellow precipitate on the addition of phosphate of soda and of the soluble arsenites, a red-brown by arseniates, a crimson by the chromates, and white by ferrocyanide of potassium, are further characteristics of the soluble salts of silver.

Tin and lead are the most rapid precipitants of metallic silver from the nitrate; cadmium, zinc, copper, bismuth, and antimony are more slow in their operation, and mercury still more tardy. Chloride of silver is rapidly reduced by most of the metals which form soluble chlorides, such as zinc, iron, cadmium, cobalt, and arsenic. Zinc, copper, and arsenic rapidly reduce the ammoniacal solution of oxide of silver. Of all the metallic precipitants, zinc and cadmium are the most effective; but when zinc or antimony are used, the separated silver contains those metals.

The solubility of silver in nitric acid, and the complete insolubility of its chloride in acid solutions, render the separation of silver from other metals in most instances an easy operation. When its amount is to be estimated quantitatively, the alloy or pulverized ore is dissolved in nitric acid, and the precipitation of the silver in the form of chloride is effected by the addition of a small excess of hydrochloric acid. In order that a dense precipitate may be obtained, the solution should be heated nearly to the boiling-point previous to the addition of the precipitant. When the whole of the chloride has settled at the bottom of the vessel, the supernatant liquor is carefully drawn off by means of a glass siphon; and the chloride, after being well washed by repeated decantations with water slightly acidulated with nitric acid, is transferred to a thin porcelain capsule, the weight of which has been accurately ascertained and noted down. The chloride, when placed in this capsule, is first carefully dried in a water-bath, and then heated over the flame of a gas-burner or spirit-lamp, until it has become fused, when the crucible and its contents are again weighed. The difference between the first and second weighings gives the amount of the chloride, from which that of the silver can be deduced by the simple proportion:—

As 100 : 75.27 :: K, or the weight of chloride obtained; since every 100 parts of the chloride correspond to 75.27 parts of metallic silver.

ASSAY OF THE ALLOYS AND ORES OF SILVER IN THE DRY WAY.—In this process the object sought is to obtain the silver and other metals that may be present in the form of an alloy with lead, which is afterwards passed to the muffle and expelled in the ordinary way; in the latter, the method adopted is founded upon the simple process which has just been described.

In assaying the ores of silver, the preliminary operations to which the minerals are subjected, and the form of the cupels and other apparatus employed, have been fully described in connection with the analogous processes followed in the assaying of gold ores; and, therefore, it will be quite unnecessary to repeat them in this place. To obtain an alloy with lead, with a view to cupellation, ores of silver, in which the metals that are present exist in the form of reducible oxides, are commonly fused with a mixture of litharge and finely-powdered charcoal. The proportion of litharge employed for this purpose, says PHILLIPS, must be varied according to circumstances, as the resulting button of alloy should not be too rich, since in that case a portion of the silver is lost in the slag; nor too poor, as the cupellation would then occupy a long time, and a loss through sublimation be entailed. In ordinary cases, if four hundred grains of ore be the quantity operated on, a button of two hundred grains will be a very convenient amount for cupellation; and this may be obtained by the addition of three hundred grains of litharge, and from seven to eight grains of finely-powdered charcoal. The whole is to be well mixed with two hundred grains of carbonate of soda, on a sheet of highly-glazed paper, and afterwards introduced into an earthen crucible, of which it should not fill more than two-thirds the capacity. This is now covered with a thin layer of borax, and fused in an ordinary assay furnace—care being taken to withdraw it from the fire as soon as a liquid and perfectly homogeneous slag has been obtained, as the unreduced litharge would otherwise be liable to cut through the pot and spoil the experiment. When it has sufficiently cooled, the crucible is broken, and the button of alloy obtained is passed to the cupel. When other minerals than oxides or carbonate are to be examined, the addition of charcoal, or any similar reducing agent, becomes in many instances unnecessary, as litharge readily attacks all the sulphides, arsenio-sulphides, *et cetera*, and oxidises nearly the whole of their constituents, with the exception of silver, whilst a proportionate quantity of metallic lead is at the same time set free. The slags formed in this way contain the whole of the excess of litharge added; and the button of alloy produced is subjected to cupellation in the usual manner.—*Phillips*.

In the assay of alloys of silver by cupellation, the directions which are given in Vol. II., page 303, in connection with the assaying of gold, render unnecessary a repetition of all the details of the process, which consists, as there stated, in the oxidation of the lead and other oxidisable metals, and their absorption by the cupel. From the circumstance that the plate and silver money of all European nations are alloyed with copper, the mixtures of these metals are those which most frequently engage the attention of the assayer; and the point to be chiefly attended to is the amount of lead necessary to be added to perform the cupellation efficiently. This amount should be greater, in proportion as the quantity of copper is more considerable; but, in cupelling an alloy of silver and copper, the same amount of lead cannot safely be added as in treating an alloy of copper and gold, as the greater volatility of the silver would cause a consider-

able loss of that metal before the whole of the lead could be absorbed. In this case, therefore, the following table, showing according to D'ARCET, the amount of lead necessary to effect the proper cupellation of various alloys of silver and copper, must be substituted for that given at the page above referred to:—

Standard of silver.	Amount of copper alloyed.	Quantity of lead necessary.	Quantity of lead in relation to that of copper.
1000	0	3-10th*	0 to 0
950	50	3	60 to 1
900	100	7	70 to 1
800	200	10	50 to 1
700	300	12	40 to 1
600	400	14	35 to 1
500	500	16 to 17	32 to 1
400	600	16 to 17	27 to 1
300	700	16 to 17	23 to 1
200	800	16 to 17	20 to 1
100	900	16 to 17	18 to 1
Pure copper	1000	16 to 17	16 to 1

* Even with pure silver it is found necessary to add a little lead on the cupel, as the button would not otherwise assume the rounded form which is required.

In this table the numbers in the third column, which express the quantity of lead necessary to be added in each case, are multiples of the weight of alloy on which the operation is performed. Hence, in the third line, for example, in which the alloy consists of 900 of silver, and 100 of copper, for each grain of alloy taken, seven grains of lead will be necessary; and as each grain of alloy contains only one-tenth of its weight in copper, it follows that the ratio of the lead to the copper is as seventy to one. It will be observed that, even with pure silver, it is found necessary to add a little lead on the cupel, the reason of which is, that the button of silver would not otherwise assume the rounded form required. It will be remarked, also, that here, as in the table given for an alloy of gold and copper, the proportion of lead to be employed for a silver alloy below the standard of 500, remains constantly the same.

Although silver is not appreciably volatilized when melted alone, yet it is so to a certain extent in the presence of lead; and therefore the cupellation should be made at the lowest temperature at which the absorption of the litharge can be effected; and even when every precaution is used, there is always a loss of silver in cupellation, for which allowance must be made in finally calculating the per centage. The table adopted for this purpose at the French mint is given in Vol. II., page 304, to which the reader is referred.

When other metals besides lead and silver are present in an alloy, the cupel usually affords indications, from which it is easy to judge of their nature, and roughly of the amount in which they exist. Mr. PHILLIPS, in his excellent manual of metallurgy, gives the following directions for this purpose:—Pure lead stains the cupel a straw-yellow color, sometimes verging on orange. Copper gives a grey or dark-brown tint, according to its quantity. Iron produces a black stain, which is chiefly formed shortly after the commencement of the operation, and gives rise to a dark ring around the sides of the cupel. Zinc leaves a yellowish stain on the cupel, and produces, during the process of cupellation, a luminous white flame and abundant fumes of the same color, which carry off

with them a considerable amount of silver. Tin produces a grey slag, and antimony leaves a spongy yellow scoria, which causes the circumference of the cupel to effloresce and split off. The two last-named metals render the cupellation of the alloys in which they exist extremely difficult, and necessitate the employment of a large quantity of pure lead, in order to carry off the insoluble oxides formed. When assays of alloys containing silver are frequently to be made by cupellation, it will be found extremely convenient to keep in the laboratory a supply of poor lead, ready weighed out into pieces of fifty and one hundred grains; by this means the standard of the lead being previously known, it becomes easy, by merely counting the number of pieces added, to know exactly what deduction is to be made for the silver in the poor lead at the termination of the cupellation.—*Phillips*.

Humid Method of Assay.—The operation is the same as that described above under estimation of silver, except that instead of collecting and weighing the argentiferous compound, graduated test liquors are employed, and the silver estimated from the volume of such solutions required to precipitate the silver completely. Although the method by cupellation was found to be convenient, where a number of assays were required to be conducted at the same time, and was therefore, until of late years, exclusively adopted at the different mints, yet the results obtained by this method not being perfectly accurate, the French Government in 1829 appointed a commission for inquiring into the subject; and GAY-LUSSAC, who was one of the commissioners, proposed the adoption of the liquid method of assay, which is now generally practised, not only at the Parisian mint, but also at the similar establishments of this and other countries. Not only is greater accuracy obtained, but by successive improvements in the apparatus, the humid process is now conducted with greater facility and despatch.

In this process the standard of the alloy of silver and copper is determined by means of a solution of chloride of sodium, the strength of which has been accurately determined beforehand. Common salt, without any preliminary purification, is employed for this purpose; and the strength of the solution is so regulated, that a decilitre thereof will exactly precipitate one gramme of pure silver. In proceeding to make an assay, one gramme of the alloy to be examined is dissolved in five or six grammes of nitric acid, and to this is added from a graduated burette the standard solution of common salt, until no further precipitate of the chloride of silver takes place. When, in adding the precipitant, the point of saturation seems to be nearly attained, the bottle must be well shaken after the addition of each successive drop of the solution, in order that the liquor may become clear by the precipitation of the chloride of silver formed. When the whole of the silver has thus been thrown down, the exact quantity of the solution of chloride of sodium employed in its precipitation is read off from the graduated scale; and, by the amount used, the per centage of silver present is at once indicated.

When great accuracy is required in making the assay of a silver coin or a piece of plate, the composi-

tion of which is approximatively known beforehand, two distinct solutions of chloride of sodium are employed:—The first, which is termed the *normal solution*, is of such a strength that one decilitre will precipitate exactly one gramme of pure silver; the second, called the *decimal solution*, is only one-tenth of the strength of the first; and, consequently, a litre of it is required to effect the precipitation of one gramme of silver.

To explain the details of the process, let it be supposed that a piece of silver money of the French coinage is to be assayed, and which, in order to be of the legal standard, should contain eight hundred and ninety-six thousandths of pure silver. Instead of this, suppose the alloy in question to contain only eight hundred and ninety-six thousandths of silver, so that 1.116 gramme of the mixture corresponds to one gramme of pure silver. This quantity is cut off the coin, accurately weighed, and put into a bottle that admits of being perfectly closed by a glass stopple, where it is dissolved in from five to six grammes of pure nitric acid; and as soon as the solution has been completely effected, one decilitre of the normal solution of salt is introduced. If the alloy contain exactly as much silver as was supposed, namely, eight hundred and ninety-six thousandths, the whole of that metal will be precipitated by the quantity of solution added, and the supernatant liquor will contain no traces of chloride of sodium in excess. But if the standard be higher than was supposed, there will still remain a portion of silver in solution; and if it be less, the whole of the silver will have been precipitated, but the liquor will contain an excess of chloride of sodium.

To ascertain which of these effects has been produced, the bottle is carefully closed with its glass stopple and briskly shaken, until the precipitate has subsided, and the solution become clear. A cubic centimetre of the decimal solution, capable of precipitating 0.001 gramme of pure silver, is then introduced. If any silver remain in solution, the liquor becomes cloudy; and after being again shaken, another centimetre of the decimal solution is added. If the liquor still becomes turbid, it is again shaken and allowed to become clear; a third centimetre of the decimal solution is poured in; and so on until no further cloudiness is produced by the addition of the decimal solution. Supposing that five of the cubic centimetres of the decimal solution, successively added, have produced a precipitate, while the addition of the sixth has not affected its transparency; it may be concluded that, after the precipitation of one gramme of pure silver by the decilitre of normal solution, the liquor still contained at least four-thousandths of a gramme of silver. But as a cloudiness was produced by the fifth cubic centimetre of the decimal solution, and none by the sixth, it is evident that the liquor did not contain more than five-thousandths of a gramme of silver; and, therefore, by adding $4\frac{1}{2}$ thousandths, the exact result is certainly attained within one half-thousandth of the truth. The standard of the alloy under examination will therefore be $896 + 4\frac{1}{2} = 900\frac{1}{2}$ thousandths.

When, on the contrary, the first cubic centimetre of the decimal solution produces no precipitate in the solution of silver, which has already received the decilitre

of the normal liquid, it is evident that the standard of the alloy must be inferior to eight hundred ninety-six-thousandths. In this case, its exact composition is ascertained by means of a standard solution of silver in nitric acid, so adjusted that one litre of the liquor shall contain exactly one gramme of pure silver; this is called the *decimal solution of silver*, and is only employed when the alloy under assay proves to be poorer in silver than was imagined at the commencement of the operation. In using it, a cubic centimetre of the solution is dropped from a pipette into the bottle containing the assay; and it occasions a precipitate of salt exactly corresponding to the same volume of the decimal solution of common salt, which was added for the purpose of ascertaining if all the silver was precipitated. The liquor is then cleared by agitation, and another cubic centimetre of the silver solution is added. If this still produces a cloudiness, the bottle is again shaken; and when the whole of the chloride has deposited, a third measure of the solution is introduced; and so on until the silver solution ceases to cause any precipitate. Assuming that the first five cubic centimetres of the silver solution produced a precipitate, and that on the addition of the sixth the liquor remained perfectly clear, it is probable that the fifth cubic centimetre was not entirely decomposed; and it is usual to assume that four and a half cubic centimetres of the silver solution, have been sufficient to decompose the excess of the chloride of sodium left in the liquor after the introduction of the decilitre of the normal solution. In this case, therefore, it is evident that it will be necessary to subtract four and a half thousandths from the presumed title of the alloy, and that its standard will be correctly expressed by $896 - \frac{4}{2} = 891\frac{1}{2}$ thousandths.

Such are the details of the process, which is greatly facilitated in the different mints, and generally where numbers of assays of silver and copper alloys have to be made, by the admirable manner in which the apparatus is arranged. The normal solution of common salt is kept in a large vessel, *v*—Fig. 498—made of sheet-copper, carefully tinned on the inside, and supported on a shelf near the ceiling. To prevent evaporation, it is covered by an immovable lid, through which passes a tube, *w*, descending to near the bottom, for the purpose of admitting air to supply the place of the liquid as it is drawn off; and by means of a gauge, *p*, at the side, the quantity of solution contained in the vessel is indicated. From near the bottom of the vessel proceeds a tube, *t*, furnished with a stop-cock, *d*. The pipette, *p*, which contains exactly a decilitre of the liquid, is connected with the tube, *t*, by another tube, *t'*, which contains a thermometer. The metallic connecting piece, by which the tube, *t'*, communicates with the pipette, *p*, is provided with two stopcocks, *r r'*; the stopcock *r'*, shown also separately in the figure, is so constructed as to allow the air to escape in proportion as the solution enters the pipette. In conducting an assay, the operator closes the extremity of the pipette with the fore-finger of the left hand, and with the right opens the stopcocks, *r r'*. When the pipette is filled with the normal solution of chloride of sodium a little above the mark *m*, the taps, *r r'*, are

closed; and the pipette remains charged with the solution after the finger is removed. On the table below this apparatus is a sliding support, *s*, on which the bottle containing the solution of the alloy in nitric acid is secured by means of a case of copper, *b*, and near it is a small stand containing a sponge, *n*, covered by a piece of fine linen, and arranged at the exact height of the beak of the pipette. The assayer now slides the plate, *p*, in the grooves of the stand, *s*, so that the sponge may come in contact with the end of the pipette; and, by carefully admitting air through the stopcock, *r'*, the liquor is allowed to descend until it exactly reaches the line, *m*, scratched on the glass. The last drop of the solution, which would otherwise remain attached to the beak, is taken off by the sponge; and as the latter becomes saturated, the solution

passes down through the hollow stem on which the sponge is supported into the cylindrical vessel beneath. The operator now draws the slide forward until it is stopped by a peg, which arrests it when the mouth of the bottle, *b*, is immediately under the beak of the pipette; the stopcock, *r'*, is then again opened, and the solution flows into the bottle.

As it generally happens that several assays are being made at the same time, they are put, when weighed out, into as many bottles arranged in a metal frame like a cruet-stand—Fig. 499—each being marked with its own number, and, by the side of each bottle, is a small cup for holding the stopple. After the introduction of the nitric acid, the stand is placed in hot water for the purpose of facilitating the solution. When this is completely effected, the nitrous fumes are removed from the bottles by gently blowing into them through a glass tube; and a decilitre of the normal solution is added to each in the manner which has just been described.

The bottles are then placed in another metal frame *M*—Fig. 500—which is similarly provided with cases or compartments for each, and is suspended from the extremity of a steel spring, *s*, while it is steadied below by an elastic band, *p*, of vulcanized india-rubber.

Fig. 498.

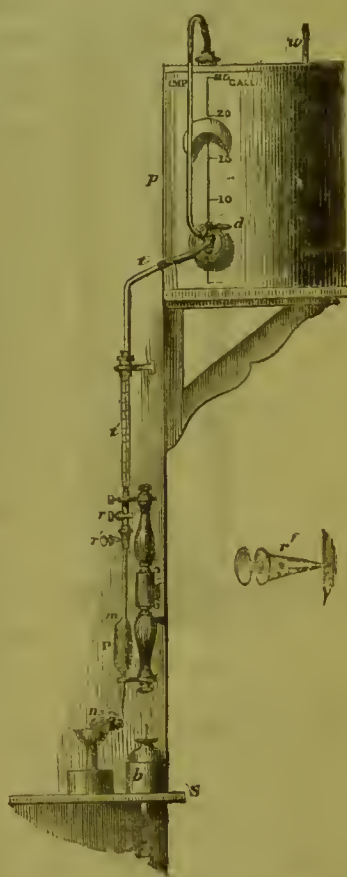
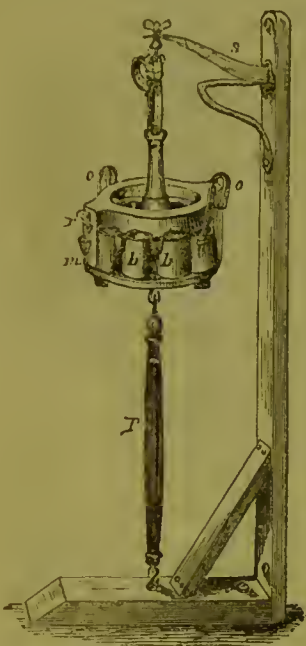


Fig. 499.



The bottles, after being carefully closed by their stopples, and secured in their places by a kind of collar—Fig. 501—which, when thrown up, is supported by a rest *r*, are well shaken by an assistant, who

Fig. 500.



takes hold of the handles, *o o*, and briskly agitates the whole apparatus for some minutes. As soon as the liquors have in this way been rendered clear, the bottles are removed from the frame *M*, to a black table, divided into compartments, which are numbered to correspond with the numbers on the bottles. The decimal solution, which is contained in a phial with a pipette passing through its stopple, is now employed for determining the exact standard of the several assays. On the surface of the pipette a line is drawn, so graduated as to enable the operator to measure out exactly one cubic centimetre

of the solution, which he does by applying the forefinger to the upper extremity of the tube; and the latter, while thus closed, being removed from the bottle, is then allowed to drop, by the cautious admission of air, until the liquid has fallen to the level of the line marked on the glass. The top of the tube is again stopped by the finger; and the cubic centimetre of solution is transferred to the first bottle of the series, into which it is allowed to flow by simply removing

the finger. In the same manner an equal quantity of solution is added to each of the other assays.

Fig. 501.



The operator now examines each of the bottles in succession, and makes a mark with a piece of chalk on the black table before those bottles in which he observes that a precipitate has taken place. These are again taken to the agitating apparatus, in which they are briskly shaken until the liquors have again become clear, when they are restored to their places on the black table; and another cubic centimetre of the decimal solution is added to each bottle in which a precipitate was obtained by the last operation. This process is continued until all the bottles cease to give precipitates; and, on counting the number of chalk marks before each, the number of cubic centimetres of the decimal solution which have been added to each is ascertained. From this number must be deducted half a centimetre in each case, to allow for the superfluous quantity which may have been added the last time, a portion only of which has probably been decomposed.

The normal solution of chloride of sodium is prepared at the temperature of 59° Fahrenheit; but as the density of the solution varies with the temperature

of the air, it is necessary to construct a table of corrections to be employed when the assays are conducted at a higher or lower temperature. For this purpose the thermometer contained in the tube, *t*—Fig. 498—should be consulted, and the correction read off from the prepared tables; but, in most instances, the assayer makes an experiment every morning on the saline solution with one gramme of pure silver, and from the result obtained he is enabled to correct any error arising from change of temperature, as well as from want of due care in the preparation of the normal solution.

The standard solution of chloride of sodium is usually prepared in considerable quantities at a time; it is made by dissolving five hundred grammes of common salt in four litres of water, and filtering. The additional quantity of water that would be required for the normal solution, supposing the chloride to be pure, is now added; and the solution is carefully adjusted to the exact standard by adding a decilitre to a solution of one gramme of pure silver in nitric acid. The liquor is clarified by agitation; and by the addition of successive centimetres of the decimal solution either of silver or chloride of sodium, the exact amount of free silver or chloride, as the case may be, remaining after the addition of the decilitre of normal solution, is accurately ascertained.

The decimal chloride solution is prepared by pouring a cubic decilitre of the normal solution into a bottle of the exact capacity of a litre, and filling it up with pure distilled water.

The decimal solution of silver is prepared by dissolving one gramme of pure silver in nitric acid, to which distilled water is added to make up an exact litre of the liquid.

When the alloy under assay contains either mercury or lead, the results obtained by the humid process are not exact, since these metals are precipitated with the silver, and decompose a portion of the normal solution, which vitiates the conditions of the experiment. The presence of mercury is indicated when a difficulty is experienced in obtaining a transparent solution by agitation; and when that is the case, the assay is not to be relied on. The assay of alloys containing mercury may, however, be made by the humid process, by adding a solution of acetate of soda to the nitric acid liquor containing the silver, previously to the introduction of the normal solution, as the acetate prevents the formation of the chloride of mercury.

The silver assays for the Royal Mint are now conducted by the humid method, and the following is a brief outline of the process as communicated by Dr. W. A. MILLER to Mr. TOMLINSON:—Ten grains of the alloy to be assayed are accurately weighed, and dissolved in one hundred and twenty grains of pure nitric acid. The standard solution of salt is so regulated that a thousand grains thereof will exactly precipitate one grain of pure silver. Now, taking the standard of English silver at nine hundred and twenty-five silver, and seventy-five copper, care is taken to keep an excess of silver in the solution; for if salt be in excess, however small, no amount of shaking will get it clear. Accordingly, the pipette *p*, Fig. 498, is charged with the standard solu-

tion to the mark, *m*, which is equivalent to nine hundred and twenty-three grains, a quantity which is capable of precipitating nine hundred and twenty-three grains of pure silver; the liquor is agitated for about a minute, and then allowed to settle. Ten grains of the decimal solution, capable of precipitating one-hundredth of a grain of silver, are now added: if a cloud be produced, a chalk mark is made against the bottle. The liquor is agitated for a minute, a second dose of the decimal solution is added, and if no precipitate is produced, it is thus shown that of the ten grains of the alloy, 9·235 grains consist of pure silver, the rest being alloy; thus showing a result a little below the standard. The standard solution of silver is formed by dissolving ten grains of pure silver in pure nitric acid and diluting it,

so that one thousand grains thereof shall contain one grain of silver.—*Tomlinson*.

STATISTICS.—In statistical returns of the precious metals, gold and silver are usually associated together, and accordingly the reader is referred to the tables appended to the article on GOLD, Vol. II., pages 308 and 309, for tables which exhibit the aggregate and relative amounts of gold and silver obtained from the different countries of the world, the annual consumption of the precious metals, and the amount of gold, silver, and copper monies coined at the mints of Great Britain, France, and the United States. To the ample information afforded by these tables with reference to the present or recent supplies of the precious metals, it will be sufficient to add the following:—

TABLE OF THE QUANTITIES OF SILVER BROUGHT INTO THE MARKET EVERY YEAR, ON AN AVERAGE, FROM 1790 TO 1802.

Old Continent.	Pounds avoirdupois.	New Continent.	Pounds avoirdupois.
ASIA.			
Siberia,	38,500	Central America,	1,320,000
EUROPE.		South America,	605,000
Hungary,	44,000		
Austrian States,	11,000		
Hartz and Hessa,	11,000		
Saxony,	22,000		
Norway,	22,000		
Sweden,	11,000		
France,			
Spain,			
Total of the Old Continent,	159,500	Total of the New Continent,	1,925,000

Thus, towards the close of the last century, the New Continent furnished twelve times more silver than the Old.

The following is HUMBOLDT's estimate of the annual produce of the mines of the New World at the beginning of the present century:—

ANNUAL PRODUCE OF THE MINES OF AMERICA AT THE COMMENCEMENT OF THE NINETEENTH CENTURY.

Political divisions.	Gold.		Silver.		Value of the gold and silver in dollars.
	Marcas of Castile	Kilogs.	Marcas of Castile.	Kilogs.	
Vice-royalty of New Spain,	7,000	1,609	2,338,220	537,512	23,000,000
Vice-royalty of Peru,	3,400	782	611,090	140,478	6,240,000
Captain-generalship of Chili,	12,212	2,807	29,700	6,827	2,060,000
Vice-royalty of Buenos Ayres,	2,200	506	481,830	110,764	4,850,000
Vice-royalty of New Granada,	20,505	4,714	.. ..	.. ..	2,990,000
Brazil,	29,900	6,573	.. ..	.. ..	4,360,000
Total,	75,217	17,291	3,460,840	795,581	43,500,000

Taking the dollar at four shillings, this would give eight millions seven hundred thousand pounds sterling as the total annual produce of the American mines in gold and silver. HUMBOLDT further estimated the annual produce of the European mines of Hungary, Saxony, *et cetera*, and those of Northern Asia at the same period, at about one million pounds more.

The production of gold, says McCULLOCH, has very largely increased since 1848, as compared with that of silver; and if this state of things go on, the value of silver, measured in gold, can hardly fail gradually to rise. But it is by no means clear that it will go on.

The supplies of silver are increasing in most parts of the world, particularly in Mexico and Europe. It is to be observed, however, that a comparatively inconsiderable rise in the value of silver, as compared with gold, is sufficient, unless prevented by legislative enactments, to make the latter be used in preference to the former in the currency of those countries in which both metals are legal tender.

In concluding this article, the Editor again begs to acknowledge his obligation to Mr. GEORGE BLAIR of Glasgow, for much valuable matter, and for his kind assistance, at all times cheerfully rendered.

SOAP.—*Savon*, French; *Seife*, German; *Sapo*, Latin.—The article now to be considered is one of the utmost importance, as, with the progress of civilization, it becomes an indispensable necessity to every human being; and as the art of its production is entirely of a chemical nature, the more it is studied under the guidance of chemical principles, the higher in quality and the better suited to its purpose will be the material. The theory which accounts for the union of certain principles of oils with the alkalies in the formation of soaps, is indeed as abstruse as that which relates to some of the most refined instances of affinities. The manufacture of soap is, therefore, strictly scientific; and it behoves those who desire to advance in the art, to study thoroughly the principles involved in it, so that each result may be an advancing lesson for their own profit, while it enables them to repay the benefit they have derived from chemistry, by furnishing, from their experience, new facts for the guidance of others.

Whether the extended use of soap be preceded or succeeded by an improvement in any community—whether it be the precursor or the result of a higher degree of refinement amongst the nations of the earth—the remark of LIEBIG must be acknowledged to be true, that the quantity of soap consumed by a nation would be no inaccurate measure whereby to estimate its wealth and civilization.

Of two countries with an equal amount of population, the wealthiest and most highly civilized will consume the greatest weight of soap. This consumption does not subserve sensual gratification, nor depend upon fashion, but upon the feeling of the beauty, comfort, and welfare attendant upon cleanliness; and a regard to this feeling is coincident with wealth and civilization.

The rich, in the middle ages, concealed a want of cleanliness in their clothes and persons under a profusion of costly scents and essences, while they were equally luxurious in eating and drinking, in apparel and horses. With civilized nations at the present time, a want of cleanliness is equivalent to insupportable misery and misfortune. The remission of the soap duty in Great Britain, which, so long as it remained unrepealed, prevented the adoption of all improvements in the manufacture, has enabled British to compete more successfully with foreign manufacturers; and it may now be hoped that this branch of industry will still further progress, so that an abundant supply of this necessary, and indeed indispensable article of domestic use, may be more easily obtainable by all.

In proof of the injurious influence of the excise duties on this and other branches of manufacture, it may be stated that the process for its production has undergone little or no alteration for the last two or three centuries. Now, however, that the manufacturer is not restricted as to the choice of materials, it remains only for the chemist to supply other and cheaper ones, and to guide the practical man as to the best method of combination; and, doubtless, diligent inquiry will reward those who enter upon the subject in a truly scientific spirit.

The term soap was formerly applied to all compounds consisting of an alkali, an alkaline earth, or a metallic oxide, united to a fatty or oily acid, or other substance of an unctuous or oleaginous nature. The extended meaning of the term is, however, not recognized; it is now applied to those combinations of grease or oil with the alkalies which, by their peculiar properties and solubility in water, aid the removal of grease and dirt in the processes of washing and scouring. This cleansing influence is due to what is termed a detergency; that is, a power of rendering soluble in water the adhering dirt of the clothes and the skin, to which purpose soap is almost exclusively applied. The alkalies themselves—potassa and soda—possess this property of detergency; and the former, potassa, under the form of wood ashes, was used in the remotest ancient times by the Hebrews, Egyptians, and Greeks, as an aid to cleansing processes. Free alkali is, however, possesses a solutive property over fibrous materials, over even human skin, and hence the necessity of combining it in such a manner as to modify its injuriously corrosive action.

The remedy is the substitution of soap, which, by its slight excess of alkali, rendering soluble in water all the dirty grease of the clothes and oily exudations from the pores of the skin, is at the same time detergent itself; for, though composed of oil and alkali in a state of combination, it still possesses the influence of the latter without any of its hurtfulness. Oleate of oxide of lead, formerly called *lead soap*, is insoluble, and constitutes the diachylon plaster of pharmacy. The analogous salts of zinc and lime, formerly termed *zinc soap* and *lime soap*, are also insoluble.

HISTORICAL NOTICE.—Although the word *soap*, or rather *sope*, is occasionally met with in the translation of the sacred records, it must not be supposed that the substance now known by that name was used by the Israelites. The word so rendered, doubtless, refers to the juice of some plant, or more probably to the ashes of a plant; as the substance in question appears to have detergent properties. The earliest mention of the term *soap*, as applied to the substance now under discussion, occurs in the writings of PLINY, who also describes a process for its preparation differing but little from that pursued at the present day. This writer ascribes its invention to the Greeks, from whom the Romans, and subsequently other nations, derived a knowledge of its manufacture. HOMER makes no mention of soap, and it was doubtless unknown to him. In the excavation at Pompeii a complete soap-boiling establishment was discovered, containing soap still perfect, though it must have been prepared upwards of seventeen hundred years. The Editor was greatly interested inspecting the factory.

The Germans were at a very early period distinguished for their production of superior soap, and hence probably the Latin term *sapo*, from the original German *seife*, now written *seife*, and from this by a transposition of letters, the English *soap* is derived. Owing, in a great measure, to natural advantages of the country, France is now the great mart for soap, and especially for toilet soaps.

MATERIALS.—The materials used in the manufacture of soap, are the various kinds of oil or fat, resin, and the alkalies, potassa and soda. All oils and fats of whatever kind, vegetal or animal, yield soaps, when treated with alkali, as will be subsequently described. Only a very limited number, however, is used in this manufacture; and these such as may be obtained at a very low price compared with that of the others. In Great Britain palm-oil is probably consumed in greater quantity than any other, and principally in the production of hard soap; for soft soaps, the various kinds of fish-oils, the drying oils from seeds, and tallow are mostly employed.

In France, and on the Continent, olive oil is extensively used in soap-making; and for soft soaps, hemp-seed oil is highly valued.

Tallow, saponified with soda, yields white curd soap; this, formerly much used for domestic purposes, is superseded in great part by the softer, and otherwise superior palm-oil soap. Cocoa-nut oil soap, on account of its property of dissolving pretty readily in salt water, is useful for washing during long sea voyages. Of all soaps, the most emollient are those of palm-oil, castor oil, and of spermaceti; yet these are not nearly so extensively used by the perfumer, or for toilet purposes, as the curd or ordinary tallow soap. Though it is of the utmost importance that the manufacturer should be fully acquainted with the peculiar properties, not only of the oils generally, but of the several individual kinds, still it will not be necessary to repeat here what has already been stated in the article specially devoted to the consideration of that subject.—Vol. II., page 597, *et seq.*

Most of the oils and fats are met with in commerce in a sufficient state of purity for their conversion into soaps without previous preparation.

Palm-oil, however, and occasionally tallow, are exceptions to this rule, and, therefore, the methods most effectual for their purification before being used in the manufacture will be afterwards stated. The destruction of the coloring matter is the object of these processes, and though described with a special view to the decoloration of palm-oil, they are generally equally applicable for tallow and other oils or fats which it may be necessary to purify more completely. The admirable investigations of CHEVREUL relative to the constitution of fatty bodies, and of LIEBIG as to the peculiar behavior of soap with various saline solutions, have greatly simplified the description of the several operations in the soap manufacture; and one can now understand the reason for the several operations, and trace with accuracy the changes that take place throughout.

Nevertheless, much room remains for future investigators in this wide field; and many improvements may still be expected from further research. Tallow, olive, palm, and cocoa-nut oils, oleic acid, and resin are used for the production of hard soaps; fish and seed oils, on the contrary, for soft soaps. The mixture of oleic acid with small quantities of stearic and margaric acids, which is obtained in the separation of stearic acid by pressure, as described under the article CANDLE, affords an excellent soap, the production of which is a secondary

process in stearic-acid manufactories: it is prepared so much the more readily as the fat is already decomposed, and the acid merely requires neutralization with alkali.

Experiments were made by DARCET, LELIÈVRE, and PELLETIER, on the relative value of different kinds of oil and fat in the manufacture of soap. The oils or fats were saponified by means of caustic soda lies, and the products were, therefore, soda soaps. The results of these experiments were as follows:—

Three pounds of olive oil gave a block of soap weighing six pounds ten ounces, which, on exposure to the air for two months, became four pounds fifteen ounces. It was then dry and perfectly solid, of excellent color, resembling that of Marseilles soap. By further exposure in a dry place it became still lighter, owing to loss of water.

Sweet almond-oil soap was found to be next to the olive-oil soap in consistency. This was very white, uniform, and of an agreeable odor. Its weight from three pounds of oil was five and a half pounds; and, after two months' exposure, it lost one pound of water. *Rape-seed oil soap* is of a greyish-yellow hue, is more consistent than that of colza oil, and possesses the peculiar odor of the oil from which it is produced.

Oil of beech-nut soap is of a dirty-grey color, softer than the preceding, and has the smell of the oil. This soap is greasy, pasty, and clammy, and when exposed to the air becomes yellow.

By associating these oils with proportionate quantities of suet or tallow, mixtures will be formed, of which soaps of proper quality and consistence can be made. The soaps made from *poppy oil* are of a dirty grey, without any disagreeable smell; are clammy, and of medium consistence. They become yellow in the air, and, when exposed to cold, become soft at the surface. This oil, when mixed with the greases, yields a soap much resembling in appearance that of olive oil.

Hemp-seed oil soap is of a green color, very pasty, and so soft that the least addition of water renders it liquid. Exposed to the air, it loses its green tint exteriorly, bleaches, and afterwards becomes brown. *Nut-oil soap* is of a yellowish-white color, with but little consistence, is greasy and clammy, and assumes a brown appearance on exposure. *Linseed oil* yields a whitish soap, which, however, becomes yellow by contact with the air. This soap is greasy, pasty, and viscous, of a slight consistence, and powerful odor, and is reduced to a thin paste by a slight addition of water. *Sperm-oil soap* is of a dirty-grey color. It retains the peculiar smell of the oil, becomes reddish-brown and of some firmness, but much less than olive-oil soap.

Soap prepared from *fish oil* is very similar to the last named. *Cod-liver oil soap* differs only in having a more unpleasant smell and less consistency. *Suet or tallow soap* is white and solid, and has a slight odor of the fat. Exposed to the air, it loses water, and becomes brittle. Soap prepared from *lard* is very white, solid, inodorous, and especially valuable for the production of toilet soaps. *Rancid butter* yields a soap which is white, and in properties similar to tallow soap, but retains a rancid smell. *Castor oil* and *spermaceti* soaps are emollient, and especially applicable to toilet pur-

poses. Soap, made from palm oil is little inferior to castor oil or spermaceti soap. Lastly, soaps prepared from drying oils are usually soft and flabby.

The appended table shows the quantity of soap obtained from three pounds of each of the oils mentioned above, saponified with caustic soda solution.

Oil or fat.	Color of the soaps.	Quantity obtained as taken from the frame.	Loss of weight in pounds and ounces.	Time.
Olive oil,	White,	6 lbs. 10 oz.	5 lbs. 0 oz.	2 months.
Sweet almond oil,	White,	5 " 11 "	4 " 6 "	2 months.
Colza oil,	Lemon-yellow,	5 " 14 "	5 " 0 "	15 days.
Rapeseed oil,	White,	6 " 8 "	5 " 0 "	20 days.
Beech-nut oil,	Dirty-grey,	5 " 4 "	4 " 13 "	2 months.
Poppy oil,	Grey,	4 " 8 "	4 " 6 "	45 days.
Hempseed oil,	Green,	5 " 0 "	4 " 14 "	15 days.
Nut oil,	Deep yellow,	4 " 7 "	4 " 6 "	15 days.
Linseed oil,	Yellowish,	5 " 0 "	4 " 12 "	1 month.
Sperm oil,	Dirty-grey,	4 " 12 "	4 " 10 "	15 days.
Fish oil,	Reddish-brown,	4 " 11 "	4 " 8 "	1 month.
Cod-liver oil,	Dirty-grey,	4 " 14 "	4 " 12 "	15 days.
Suet or tallow,	White,	8 " 4 "	6 " 0 "	2 months.
Lard,	White,	8 " 3 "	5 " 0 "	2 months.
Washed rancid butter,	White,	11 " 0 "	7 " 0 "	2 months.

PALM OIL.—The sources, preparation, properties, and composition of this valuable oil, have been fully discussed in a previous article, Vol. II., page 618. It remains here to notice more particularly the treatment to which it is necessary to submit it, to remove the coloring matters, *et cetera*, previous to its employment in the manufacture of soap. Its rapid rise in commercial importance during the last half century exceeds that of nearly every other article imported, as will be seen by the following statistics:—

	Hundredweights.
Imported in 1820,	17,456
" 1830,	213,476
" 1840,	315,503
" 1850,	447,796

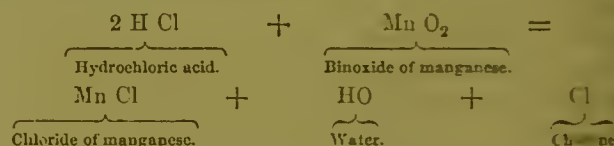
At the present time palm oil is imported to the amount of upwards of twenty-five thousand tons annually.

As it arrives in this country, this oil is tinged of a peculiar and characteristic orange-red color, which renders it unfit for use in this manufacture in its natural state. The coloring matter, it should be observed, is not proper to the pure oil, which, in a state of chemical purity, is perfectly colorless. There is associated with the oil, however, and extracted with it from the palm a peculiar principle, which in the course of time undergoes spontaneous decomposition, assuming at the same time a characteristic color.

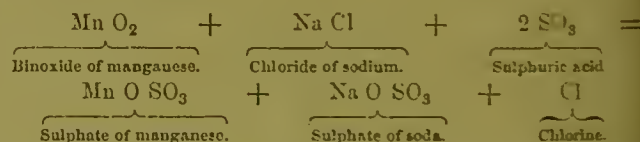
Numerous processes have from time to time been adopted to effect the decoloration of palm oil, nearly all of which depend upon the application of nascent oxygen produced through the decomposition of various compounds, from which it may be liberated with a greater or less degree of facility.

The old method consisted in the employment of nitric acid; but this method, though not objectionable on account of its cost, has the disadvantage of impairing the peculiar violet odor of the oil upon which its value chiefly depends; whilst, at the same time, though the coloring matter is destroyed, the oil is not perfectly bleached, and hence it yields a soap of a greyish-yellow hue. Neither is chlorine well adapted for the purpose, though the coloring matter is readily decomposed by it; for this agent exerts an injurious action on the oil itself, developing a brown tint, and impairing its

consistence. Nevertheless, chlorine has been used to a great extent for depriving palm oil of its color; the materials for generating the chlorine, namely, binocide of manganese and hydrochloric acid, or, instead of the latter, chloride of sodium and sulphuric acid, being introduced directly into the melted oil. The changes that ensue when hydrochloric acid is employed, may be shown as follows:—



and when, in the place of hydrochloric acid, chloride of sodium and sulphuric acid are used, the reaction may be thus stated:—



As to the precise manner in which chlorine effects the destruction of coloring principles, this is a question upon which there is much difference of opinion. It cannot be questioned, however, that the injurious action of free chlorine on the substance of oils is owing to its powerful affinity for hydrogen, and that by the abstraction of this element more or less completely from the oil, entirely new and probably substitution compounds are produced, which will account for the alteration in the color and consistence of the oil.

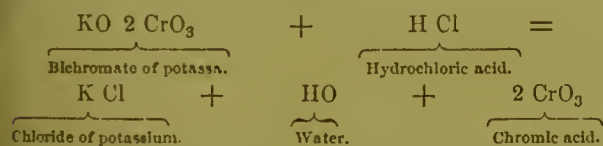
Of all methods of bleaching palm oil, that which effects the decomposition of the coloring matter most completely, is that originally proposed and patented by Mr. WATT, in which the decoloring agent is nascent oxygen produced by the decomposition of chromic acid. The process is commenced by heating the oil by steam in an ordinary boiling cauldron for half an hour; it is then allowed to stand at rest to deposit impurities, and when cooled down to about 130°, it is drawn off from the sediment and condensed steam, and placed in wooden vessels, each capable of containing two or three tuns. To each half tun of oil, thus far freed from extraneous matters, the following mixture is added; a saturated aqueous

solution of twelve and a half pounds of bichromate of potassa, four pounds of concentrated sulphuric acid, and about twenty-five pounds of strong hydrochloric acid. These are the proportions recommended by the patentee, but are not always strictly adhered to; many bleachers using to the above quantity of oil, ten pounds of the bichromate, and forty of the hydrochloric acid. After being well agitated with the mixture for a few minutes, the oil becomes of a black color; in a short time, however, this changes to dark green, and soon afterwards to light green; and at the same time a thick froth appears on the surface indicating the termination of the reaction. The oil is now examined by taking out a small portion and allowing it to settle, and if not sufficiently decolorized an additional portion of the bleaching mixture is added.

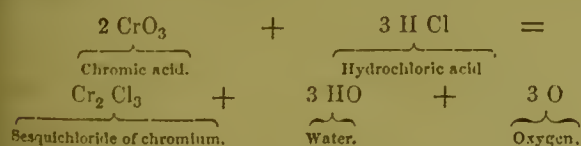
After complete decoloration, which is effected in from ten to fifteen minutes, the oil is permitted to remain undisturbed for about half an hour, so as to allow the deposition of the aqueous solution of chloride of chromium, sulphate of potassa, and other foreign matters; after which the clear oil is drawn off into a wooden vat, mixed with a little fresh water, and again heated for a short time by means of steam.

After being once more allowed to rest to deposit water, *et cetera*, the oil may be siphoned or otherwise drawn off, and is fit for use.

As already mentioned, the decoloration is effected in this process by the agency of nascent oxygen. When the solution of bichromate of potassa and hydrochloric acid are mixed, the acid of the bichromate is liberated, the oxygen of the potassa seizes the hydrogen of the acid forming water, and the chlorine unites with potassium to produce chloride of potassium as represented in the annexed equation:—



After this decomposition, the mixture, containing an excess of hydrochloric acid, is added to the melted oil, and on coming in contact with the organic matter, a further change takes place between the hydrochloric and chromic acids. The latter is reduced to sesquioxide of chromium, and this with hydrochloric acid yields sesquichloride of chromium; water is formed, and oxygen is set free as follows:—



The liberated oxygen is seized by the coloring matter, and the green sesquichloride of chromium, chloride of potassium, *et cetera*, are found in solution in water at the bottom of the vat. The sulphuric acid directed to be added by the patentee, does not appear to be essential to the operation, and is indeed omitted by many bleachers. Oil once bleached by this process may be preserved from acquiring odor, and the soap made from it does not become tinged like that made from oil bleached by other methods.

Another process for bleaching palm oil, depending, like the preceding, on the decoloring power of oxygen at the instant of its liberation, was patented some years ago by Mr. WATSON. In this method manganate of potassa or chameleon mineral is used as the source of oxygen, and after solution in water is added to the melted oil in the proportion of one-twentieth of its weight, the oil being placed in a wooden cask, and mixed with dilute acid. The whole is to be well mixed, and gradually heated to 212° , and maintained at that temperature for an hour. The rest of the process is conducted precisely as directed when bichromate of potassa and hydrochloric acid are employed.

On account of the tendency of the solution of manganate to spontaneous decomposition, the mixture of dilute acid and fat, to which it is to be added, should be at the lowest temperature consistent with its fluidity. Owing to this peculiarity of the manganate, as well as for many other reasons, it is not likely to supersede the employment of bichromate.

When palm oil is to be used in the production of yellow soap, the most economical mode of bleaching is by the process patented by Mr. ARTHUR DUNN. This method, which is also applicable to other oils and fatty matters of a like nature, consists in the exposure of the oil to the combined influence of air and heat. The air is forced beneath the surface of the oil through pipes, by means of a blowing apparatus, and then allowed to rise through the liquid in numerous small streams; the oil being maintained at a temperature between 170° and 230° by steam pipes or other means. A hood communicating with a chimney is placed over the vessel containing the oil, for the purpose of conducting away the unpleasant vapors which are disengaged. This process appears to be an improvement of the method first recommended by Mr. CAMERON through the Society of Arts. This gentleman directed the heated oil to be violently agitated by means of a horizontal fan, revolving at the rate of about six revolutions a minute, and it was stated that by this method four tons of oil may be decolorized in ten hours at one operation, and at the expense of half a ton of coals.

All that is essentially necessary to effect the bleaching is obviously the exposure of the oil to the combined influence of air and heat, and with this view the process of Mr. DUNN seems as complete a method as could be devised. According to PARNELL, the oil should not be maintained at a temperature exceeding 180° during the operation of blowing in the air. He recommends, however, that at the commencement of the process it be heated to 212° , and then suffered to cool a little. This is necessary, inasmuch as the air has but little effect as long as water is present; but when this is completely expelled, the bleaching commences immediately. The oxidising action of the air on the coloring matter of palm oil, as PARNELL observes, seems to be accelerated by combining the influence of light with that of heat. With this end in view, the oil is sometimes placed in a thin layer, on the surface of a large shallow uncovered vat. Several of these vats, each about a foot in depth, may be heated by means of steam passed through serpentine

lead pipes proceeding from a common boiler; one extremity of each tube may terminate in a receiver for the condensed water, and the latter may be returned to the boiler. Each vat is first two-thirds filled with water, and when this is become hot, a sufficient quantity of palm oil is introduced to form when fluid a layer of about two inches in depth, and this should be maintained during the whole process at a temperature as near 212° as possible. To preserve an equal temperature throughout the fluid, the steam may be admitted at opposite ends of the vat, and separated in contrary directions by two distinct serpentine tubes. Both air and light having access, the time required for the decoloration of the oil at a temperature approaching to 212° , is from ten to fifteen hours: the thinner the stratum of oil, the more rapid is the process. The rapidity of the bleaching action is not sensibly lessened by loosely covering the containing vessel, provided the removal of the air over the surface of the oil is not much interfered with; but if exposed to a temperature of 212° in a closed vessel, so that although light and heat have access, the air is excluded, the oil does not then become bleached; hence PAYEN, who made these observations, suggests the propriety of adopting such an expedient as will, while not excluding air, partially prevent the great loss of heat which occurs from the extensive surface of oil presented to the air in the open vessels commonly used in this method of decoloration. The bleached oil, which while fluid retains a fawn-colored tint, is after solidification of a greyish-white color.

RESIN.—Besides oil and alkali common resin or colophony also forms an important ingredient in the production of soap. The sources and method of procuring this substance have been fully discussed in a separate article, and it only remains here to treat of it as a constituent of soap. The kind used is that yielded by the common turpentine, produced by and extracted from the several species of pine.

Though employed in the fabrication of soap as a partial substitute for oleaginous or fatty material, resin does not possess a similar constitution to these matters, and, therefore, does not suffer an analogous alteration in the process of saponification. Resin contains no oxide of glycercyle or any similar body, nor indeed any base whatever. UNVERDORPEN, who made a careful examination of it, found it to be an indefinite mixture of two distinct substances possessing very decided acid properties, and which he termed sylvic and pinic acids, the latter of which is readily soluble in cold alcohol of specific gravity 0.86, and the former nearly insoluble in this liquid. The introduction of too large a proportion of resin into soaps, gives to the latter a very dark color, and also renders them much too soft for application to the purposes for which hard soaps are used. Resin is used only in the production of yellow soap.

ALKALIES.—The alkaline ingredients employed in the soap manufacture are, as already noticed, potassa and soda. Both these articles are met with abundantly in commerce in the state of carbonate, and in this condition purchased by the soap manufacturers.

The crude carbonate of potassa, termed *potash* or

pearlash, is prepared by calcining in an iron pot the residue of the evaporation of a lie obtained by leaching wood ashes in water. Its production has been fully described under the article POTASSIUM. Besides carbonate of potassa, it contains in considerable proportions, chloride of potassium, sulphate of potassa, and other salts. These, however, do not interfere materially with its application to the soap manufacture.

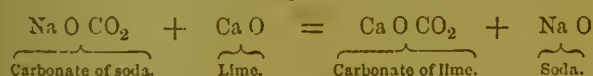
The carbonate of soda of commerce is variously designated, according to the source whence it is obtained. Barilla, a very impure variety, is in appearance a grey or bluish-grey mass, and is imported from Spain and the Levant. It is procured from the plants of the order *Chenopodiaceæ*, which, being cultivated on the coast, are, when ripe, cut down, dried, and burned in heaps; the resulting ash is barilla. Besides carbonate of soda, it contains sulphate of soda, sulphide and chloride of sodium, carbonate of lime, alumina, silica, oxide of iron, and carbonaceous matters which have escaped combustion. The quantity brought to this country is now very small; indeed soap manufacturers generally have abandoned its use. *Kelp*, another very impure carbonate of soda, is prepared in a similar manner to barilla, from the plants of the order *Algaceæ*. It contains the impurities which exist in barilla, and, in addition, an alkaline iodide. Kelp is used to a far greater extent by soap manufacturers than barilla, but its value as a source of soda is very insignificant. The greatest source of soda, both as applied to the production of soap and to all other purposes, is the *white ash* or soda ash of commerce, procured by the decomposition of common salt. The introduction of this material, though it was effected with much difficulty, has been the greatest stimulus the soap manufacture has ever received. Mr. JAMES MUSPRATT of Liverpool, who was the first to carry out LEBLANC's process on a large scale, in the year 1824, was compelled to give away soda by tons to the soap-boilers before he succeeded in convincing them of the extraordinary advantages to be derived from it. As soon, however, as he effected this, and when the soap-boilers discovered how much time and money they saved by using artificial soda, orders came in so rapidly that the Editor's father, to satisfy the demand, had his crude soda discharged red hot into iron carts, and thus conveyed to the soap manufactories.

From that period a constant race was kept up between soap-making and the artificial production of soda. Every improvement in LEBLANC's system was followed by an extension of the soap trade; and it is a curious fact, that the seaport of Liverpool exports annually more soap at present, than did all the ports of Great Britain previous to the conversion by Mr. MUSPRATT, on the large scale, of chloride of sodium into crude carbonate of soda. The manufacture of soap has, on the other hand, been a powerful stimulus to the preparation of soda, and of the important secondary product—chloroxide of calcium, or *bleaching powder*—two substances which are so intimately allied with almost all branches of chemical manufactures. Thus soap occupies one of the most important pages in the history of applied chemistry. The increase in the consumption of this article has led, moreover, to the dis-

covery of new materials for its production, and has opened new channels to commerce.

When the soda prepared from common salt was first introduced into the soap manufacture, for making yellow soap, the fabricators purchased it in the form of *black ash* or *ball soda*. This, at that time designated also British barilla, is the residue of the calcination, in a reverberatory furnace, of a mixture of sulphate of soda, chalk or broken limestone, and small coal; and when lixiviated with cold or luke-warm water, affords a solution of carbonate of soda, containing also a small quantity of caustic soda and sulphide of sodium, together with a portion of undecomposed chloride of sodium and sulphate of soda. The alkaline carbonates now used by soap manufacturers, are white ash or soda ash. This is obtained by lixiviating the above-mentioned black ash in water, drawing the solution from the insoluble matters, and evaporating to dryness. The residue thus obtained may be used for making lie; but, as it usually contains some sulphide, which, in the production of white soap, is a source of inconvenience, it is necessary for some purposes to calcine this residue at a moderate heat, whereby nearly the whole of the alkaline sulphide becomes oxidized and converted into sulphate.

This ash contains carbonate of soda sometimes to the amount of ninety-five or ninety-six per cent. It is, however, essentially necessary in the production of soap, that the alkali should be rendered caustic—that is, set free from combination by the removal of carbonic acid; as, if it be in chemical union with any other body, it has no decomposing power over the oils or fats. Even if combined with the weakest acids, saponification will not ensue; and the greatest care should, therefore, be exercised in this preliminary process—the preparation of the lies. The process for causticizing is the same in principle for the preparation both of soda and potassa lies. It depends upon the greater affinity of lime than of soda or potassa for carbonic acid, and the decomposition is one of the most simple, thus—



The proportions of soda ash and lime employed vary according to the degree of strength of the soda; similarly with regard to the potassa salt. It is, however, always an advantage to have an excess of lime over the alkaline carbonate, as in the contrary case any undecomposed carbonate is totally lost.

A fact deserving of mention in treating of the preparation of lies is, that in the process of causticizing by means of lime, a portion of the soda appears to enter into some form of combination very difficultly soluble. Mr. KYNASTON, a student of the Editor's, lately examining the calcareous deposit, found it to contain, after being well washed, soda to the amount of five or six per cent. When the deposit, after being dried, is heated to a temperature insufficient to expel carbonic acid, and, after being allowed to cool, is again drenched with water, caustic soda is then removed with great ease, and the deposit may be almost completely deprived of soda. Taking these facts into consideration, the Editor is of opinion that it would well repay the soap manufacturer to collect the lime deposit,

and, after thorough desiccation by exposure to the air, to submit it to heat until the carbonic acid is expelled. The lime now again become caustic, may be used advantageously in the preparation of fresh lie, and the process may be repeated until the deposit becomes highly charged with the impurities of the ash, when fresh lime may again be used for a new process.

Another of those progressive steps manufacturers frequently take, leading to the simplification of operations which previously had been tedious, laborious, and wasteful, has been taken in the soda trade, the especial benefits of which are to be derived particularly by the soap-maker and the public generally. This intellectual advancement consists in preparing *directly* the caustic alkali, by the use of which the soap-maker at once dispenses with a considerable plant outlay, economizes space, expedites the operations of his trade, and effects no little amount of saving in labor alone, compared with the present general practice. Besides the foregoing immediate and apparent advantages resulting in favor of the soap-maker, from the employment of caustic soda prepared *directly*, there are others of much greater importance—namely, the economy of alkali, and the readiness with which soap can be made by the use of lies, the strengths of which are immediately under control, and which cannot be obtained economically on the present causticizing system to which soda ash is submitted, unless at considerable trouble; and even then the lies are not pure, owing to the circumstance that strong caustic alkaline solutions divest carbonate of lime of a portion of its carbonic acid.

The article in question, being in the solid state, is most convenient for transit and storage. It is now prepared largely in some alkali works; MUSPRATT BROTHERS, and HUNTLEY, of Flint, North Wales, manufacture it to a very considerable extent, and the trade is likely to be greatly increased; and the Editor is convinced that its employment would be much more economical to the soap manufacturers than the present method of preparation. It requires simply to be dissolved in a given quantity of water, to produce lies ready for use, and of any required strength. In America it is now largely employed for this purpose, but in England rarely, if at all. Its introduction, though a great advantage to the soap producers themselves, will probably be a matter of as much difficulty as was that of the introduction of the so-called artificial soda, at least as regards the English manufacturer. The method of preparation of this caustic soda will be fully described in a subsequent article. It is of such a nature that it cannot be economically or, indeed, conveniently applied, except where artificial soda is produced to a considerable extent. Being perfectly free from sulphide of sodium, it is especially applicable to the production of white soaps.

Testing the Lie.—That the soap-boiler may be in a position to carry out his method accurately, and to proceed with safety, it is necessary during the lixiviation in the ash tubs, and whilst boiling the fat, that he should be able at any moment to ascertain correctly the strength of the lies. For this purpose specific gravity bulbs, or the *hydrometer*, is used. In this country Twaddell's hydrometer is most commonly employed.

The indications of such an instrument are in no kind of connection with the chemical nature of the fluid; and as the graduation is perfectly arbitrary, nothing more can be established by its application than a comparison of the densities of different liquids. As, however, a correspondence has already been established between the degrees of the hydrometer and the specific gravities, and it is also known what proportions of potassa and soda correspond to the specific gravity of different solutions, the hydrometer may be used as a means of ascertaining the amount of alkali present. The degree indicated by Twaddell's hydrometer, multiplied by five and added to one thousand, expresses the specific gravity of the fluid. A lie testing 27.50 Twaddell, for instance, has a density equal to 1.138, which is equivalent to 15 per cent. of potassa or 12.8 per cent. of soda, always supposing the lie to contain no other matters or salts which might also affect the specific gravity. This, however, is never the case with soap-boilers' lie, so that the indications are only approximations with reference to the amount of alkali, or even may be altogether fallacious. Still they are useful in a variety of ways, and are, indeed, indispensable. The practitioner is able with this instrument to follow the diminishing strength of the liquid flowing from the ash tubs or vats, and to form a just estimate of its value, when, at the same time, a test with acid proves the absence of carbonic acid. But even in the process of soap-boiling itself, the test of the lie afforded by the hydrometer, combined with the personal experience of the workman, is a clue by which he is enabled to judge whether the proper strength has been attained; knowing as he does what degree the hydrometer ought to indicate from any particular soda or potassa lie for any particular purpose. The more or less caustic taste of a lie is also a test much depended on by many soap-boilers.

SAPONIFICATION.—Oils and fats themselves are neither soluble in water nor miscible with it; but nearly all are made so by union with alkali. The process of effecting this combination is termed *saponification*, and the compound produced is *soap*—hard soap when its base is soda, but more or less soft when potassa is the alkali present. The properties and composition of the different kinds of oil and fat, as well as their behavior under the influence of various reagents, have been fully discussed in a separate article. It is, however, necessary in considering the theory of saponification, again to notice the constitution of these bodies in its bearing upon their conversion into soap. The fixed oils, as well as the animal fats, are composed for the most part of certain proximate principles, of which stearin, margarin, and olein are the most abundant. Some oils, as for instance palm oil, have constituents peculiar to themselves; but as they are quite analogous to olein, and other bodies above-mentioned, in their chemical constitution, and consequently similar in their relation to alkalies, these will serve as examples.

In animal fats stearin is usually the most abundant constituent; margarin more especially characterizes the vegetal and human fats; olein is present in both, though varying in its nature in different kinds of oil.

Stearin, margarin, and olein, however, are not free

uncombined bodies, but positive compounds, each of its respective acid with a base, termed *oxide of glyceryl*, the hydrate of which is glycerin. Thus, though the base is the same in all, the acid constituent in each of the three is peculiar. The acid in stearin is termed *stearic acid*; that in margarin, *margaric acid*; and that in olein, *oleic acid*. Stearin, margarin, and olein have, therefore, a saline constitution, and may be respectively regarded as a stearate, margarate, and oleate of oxide of glyceryl. When brought into contact with a free alkali, or a metallic oxide in presence of water, these fatty principles undergo decomposition; the alkali, or metallic oxide, being a more powerful base, seizes the oily acid, and a stearate, margarate, or oleate of potassa is formed, as the case may be. These latter compounds, when mixed with a solution of a more powerful acid, such as the mineral acids, or even of the stronger organic acids, as oxalic, tartaric acid, &c. &c., are decomposed, a salt of the base with the acid employed being produced, while the oily acids are set free, and at the instant of separation combine with a certain proportion of water. The oxide of glyceryl, liberated from the fatty principle by the action of an alkaline solution, also at the moment of separation enters into combination with a definite proportion of water, the product being glycerin, which, owing to its sweet taste, and the source whence it is procured, was originally termed the sweet principle of oils. It will now be more easily understood that the oils or fats, or the principles of which they are composed, are themselves incapable of *direct* combination with the alkalies, or other bases; or, in other words, the mixture of a fat or oil with an alkali, does not occasion the formation of soap. On the addition of water, however, with which the base of the fatty principle may combine, saponification ensues immediately. Previously to the admirable investigation of CHEVREUL, to whom chemists are indebted for a knowledge of the composition of oils and fats, and their peculiar properties and behavior, the presence of water in the process of saponification was supposed to occasion a change proportional to its elements, converting the stearin, margarin, and olein into new bodies, which from their acquired acid properties were termed adipose or saponic acids; the peculiar unsaponifiable body glycerin being left behind as an incidental product. Hence, what are now known to be positive compounds of a fatty acid with the base of glycerin, were considered as altered in ultimate composition by the action of water and alkali. This view is now known to have been fallacious, and it has been conclusively demonstrated that the acids exist ready formed in the fats, and are separated from the base-oxide of glyceryl, in accordance with that law which determines the power of stronger bases over weaker ones.

Thus, therefore, when solution of potassa or soda is boiled with oils, the fatty acids are abstracted, and the eliminated oxide of glyceryl, uniting with water, forms glycerin. And thus it is explained why the fatty acids separated from oil, estimated together with the glycerin, always exceed the weight of the oil or fat submitted to decomposition—the excess being due to the water entering into combination both with the glyceryl base, and with the fatty acids. The following diagram

will render the decomposition that ensues, when an oil is saponified, much more intelligible:—

Substances employed.	Composition.	Products of decomposition.
Fats or oils, namely, stearate, margarate, oleate, <i>et cetera</i> , of oxide of glyceryl.	<div style="display: inline-block; vertical-align: middle;"> { Stearic acid, Margaric acid, Oleic acid, + Oxide of glyceryl, </div>	Stearate, margarate, and oleate of potassa or soda, that is, soap.
Potassa or soda, Water,		Hydrated oxide of glyceryl, that is, glycerin.

Soap, therefore, it will be observed, does not result from a direct union of the fatty matter with the alkali; a further proof of which is seen when the soap obtained as above is decomposed by the agency of a stronger acid. It will be found that the acid decomposing the soap, by seizing its alkaline base, leaves the fatty material in a totally different state to that in which it existed when originally added. It is now found to possess acid properties, and to unite much more readily with alkalis; or, in other words, to be more easily saponified. This latter property is accounted for from the fact that, being in an uncombined state, the acids have no base to overcome, as was the case in the first instance. In all saponifiable fats, the same reaction ensues, though the soap produced contains different acids, according to the kind of grease or fat employed. Thus, in the case of palm oil, the soap consists for the most part of *palmitate* of soda or potassa. When spermaceti is used, the soap produced consists of *cetyl-ate* of potassa or soda, and instead of glycerin, an analogous body termed ethal is found in the mother-liquor. By far the greater majority of fats, however, yield when treated with alkalis, soaps containing only stearate, margarate, and oleate of potassa, if a soft soap, and of soda in the case of hard soaps. Resin, though employed in the manufacture of soap in the place of fixed oil or fat, is not to be considered analogous to a fat in its chemical constitution, or to be capable of forming with an alkali a proper soap by itself. Resin contains neither oxide of glyceryl nor oxide of cetyl, nor any equivalent for these substances, but is an indefinite mixture of three distinct bodies possessing well-marked acid properties; and hence named *sylvic*, *pinic*, and *colopholic* acids, each of which is capable of entering into combination with alkalis, and of readily dissolving in alkaline solutions, though totally insoluble in pure water.

For the complete saponification of fats or oils, an excess of alkali is requisite, and is so much the more willingly employed, as it can be removed again without difficulty. The production of soap is by no means a momentary process, nor can it be done with the same exactness or rapidity as the decomposition of an ordinary salt. On the contrary, the manufacture consists of a number of stages, and these occupy a considerable length of time from the first mixing of the fat with the alkali, when a sudden emulsion is produced, to the formation of soap ready for use, or even to that point when the whole of the alkali is saturated with fatty acid. Acid salts are first produced with the oily acids, and these hold the remainder of the fat in solution, or in a state of division, until it also is able to combine with alkali, and transform the acid into neutral salts, or into finished soap. This reaction may easily be observed, if the fat is boiled with one-half the required quantity

of alkali; the whole of the oil is in such case dissolved, but the solution becomes turbid on cooling, and when water is added, and the mixture again boiled, unsaponified fat separates, showing that this had only been retained in the fluid by the stearate or margarate of the alkali that had been formed.

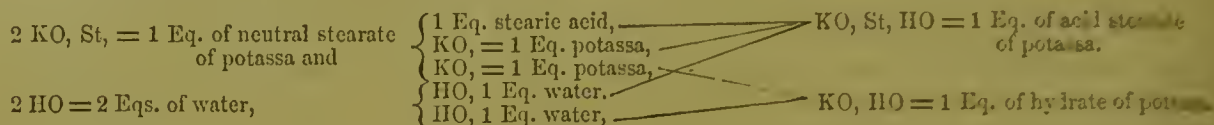
HARD AND SOFT SOAP.—Soaps are divided into two classes, differing from each other in the material from which they are produced, and are distinguished by the names *hard* and *soft soap*. Hard soaps are made from fats, or vegetal fat oils, and soda; for soft soaps, the oleaginous material is usually a fish oil or vegetal drying oil, and the alkali, potassa. Hard soaps may, however, be made with potassa, provided a solid fat be employed; but soda soaps are invariably harder than potassa soaps, the unctuous material being the same. The hard soaps of animal fats are either white or marbled, and are particularly applicable for washing the finer articles of dress, the soft soaps being more caustic than the solid soda soaps. Of the hard soaps of commerce those made with oils, with the exception of palm-oil, are mixtures of margarate and oleate, with only a small proportion of stearate of soda; those made with animal fats are mixtures of stearate, margarate, and oleate of soda. On the continent, and wherever wood is abundant, potassa is frequently introduced in admixture with soda in the production of hard soaps.

PROPERTIES OF SOAPS.—Potassa and soda soaps are readily soluble in hot water and alcohol; the addition of a quantity of water to the aqueous solution produces a precipitation, the neutral salts of stearic and margaric acids decomposing into free alkali, which remains in solution, and acid stearate and margarate of alkali, which precipitates in the form of pearly, crystalline scales. Potassa soaps are more soluble in water than those containing soda. Stearate of soda may be regarded as the type of hard soaps; in contact with ten times as much water it suffers no striking change, while stearate of potassa under the same circumstances forms a thick paste, or a viscid solution. In these respects the margarates of potassa and soda closely resemble the corresponding stearates. Oleate of soda is soluble in ten parts of water, and oleate of potassa in four parts. The latter forms a jelly with two parts, and possesses such a strong affinity for water, that one hundred parts absorb one hundred and sixty-two when exposed to a humid atmosphere. It follows, therefore, that soaps are soft in proportion to the oleates, and hard in proportion to the stearates and margarates they contain; so that the softness or hardness of soap is not solely dependent upon the base that is employed.

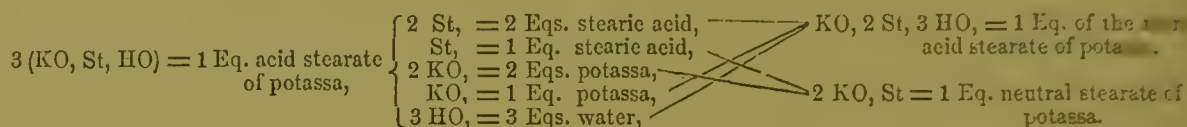
Soap of Commerce—that is, stearate, margarate, or oleate of alkali—is never dissolved by cold water without decomposition. The neutral salts are resolved into alkali, which dissolves, and into an acid salt, which is

precipitated. The same decomposition occurs when hot solutions of soap—particularly of dilute—are cooled. According to CHEVREUL, who particularly investigated this decomposition in the case of stearate of potassa, when a solution of this neutral salt— 2 KO, St —is cooled, one-fourth of its potassa remains in solution, and a

mixture of neutral with acid stearate of potassa is precipitated. If the same salt is dissolved in five thousand parts of cold water, the acid stearate— KO, St —is precipitated in the form of pearly scales, and half of the potassa remains in solution according to the following equations:—



Acid stearate of potassa, after being separated from the liquid as above, and treated with a thousand parts of hot water, is again decomposed into neutral stearate of potassa, and a still more acid stearate, as follows:—



The occurrence of these decompositions, which ensue equally with the margarates and oleates of potassa and soda, as with the stearates, affords an easy explanation of the appearance of the whitish turbidity always produced when soap is dissolved in even the purest water, and show, at the same time, that the alkalinity of soap-suds is solely due to the liberation of caustic potassa or soda; and this it is that affords the possibility of removing fatty impurities in water, which is the sole object of washing with soap.

It is of the utmost importance to the soap-boiler that he be well acquainted with the physical comportment of soaps with solutions of different salts, as, for instance, with chloride of sodium, carbonate of soda, the corresponding potassa salts, chloride of ammonium, and various others. These although not absolutely essential to the formation of soaps, are very much concerned in the separation of the foreign matters that render hard soap impure; and are also useful to impart to it the proper amount of water. In practice, a solution of chloride of sodium is always employed for this purpose. The peculiar behavior of soap with a solution of this salt is thus described by LIEBIG:—If a piece of common hard soap be placed in a solution of salt at ordinary temperature, it floats upon the surface without ever being moistened, and if the liquid be heated to boiling, it separates without foam into gelatinous flocculæ, which collect on the surface, and upon cooling unite into a solid mass, from which the solution flows off like water from fat. If the flocculæ be taken out of the hot fluid, they congeal on cooling into an opaque mass, which may be pressed between the fingers into fine laminae without adhering to them. If the solution is not quite saturated, the soap then takes up a certain quantity of water, and the flocculæ separate through the fluid on boiling. But even when the water contains one four-hundredth part of common salt, ebullition does not produce solution. If the soap is boiled in a dilute and alkaline solution of salt, and suffered to cool, it again collects on the surface of the fluid in a more or less solid state, depending on the greater or less degree of concentration of the solution; that is, on the quantity of water taken up by the soap. By boiling the dilute solution of salt with soap for a considerable time, the

aqueous flocculæ intumescence, and the mixture assumes a foamy appearance, but still they are not dissolved. As the solution separates from them. The flocculæ, however, have become soft and pasty, even after cooling, and their pastiness depends on the quantity of water they have imbibed. By still continued boiling the character again changes, and in proportion as the water evaporating renders the solution more concentrated, the latter again extracts the water from the flocculæ: the liquid, however, continues to foam, but the bubbles are larger. At length a point is attained at which the solution becomes saturated; the larger iridescent bubbles formed just before disappear, and the liquid continues to boil without froth; all the soap collects as a translucent mass on the surface, and now the solution and soap cease to attract water from each other.

If the plastic soap be now removed and cooled, while the solution is pressed out, it becomes so solid as scarcely to receive an impression from the fingers. In this state it is called *grain soap*. The addition of salt, or its solution, to a concentrated alkaline menstruum of soap in water, precipitates the soap in gelatinous flocculæ, and the mixture behaves precisely as solid soap boiled with a dilute solution of salt. Carbonate of and caustic potassa act exactly as salt in separating soap from the alkaline fluid. The application of these facts to the manufacture of soap is obvious. The fat is kept boiling in an alkaline lie until all pasty matters disappear: but the lie should have only a certain strength, so that the soap may be perfectly dissolved in it. Thus tallow may be boiled for days in a caustic potassa solution of specific gravity 1.25, without being saponified. If the lie be stronger a partial saponification ensues; but being insoluble in the fluid, the soap floats on the surface as a solid mass. By the gradual addition of water with continued boiling, the mass at a certain point becomes thick and clammy, and with more water an emulsion is formed; on continued heating, this becomes perfectly clear and transparent, if a sufficient quantity of alkali be present. In this state it may be drawn out into long threads, which on cooling either remain transparent, or are milky and gelatinous. As long as the hot mass, suffered to drop from a spatula, exhibits a milkiness or opalescence, the boiling is continued, or

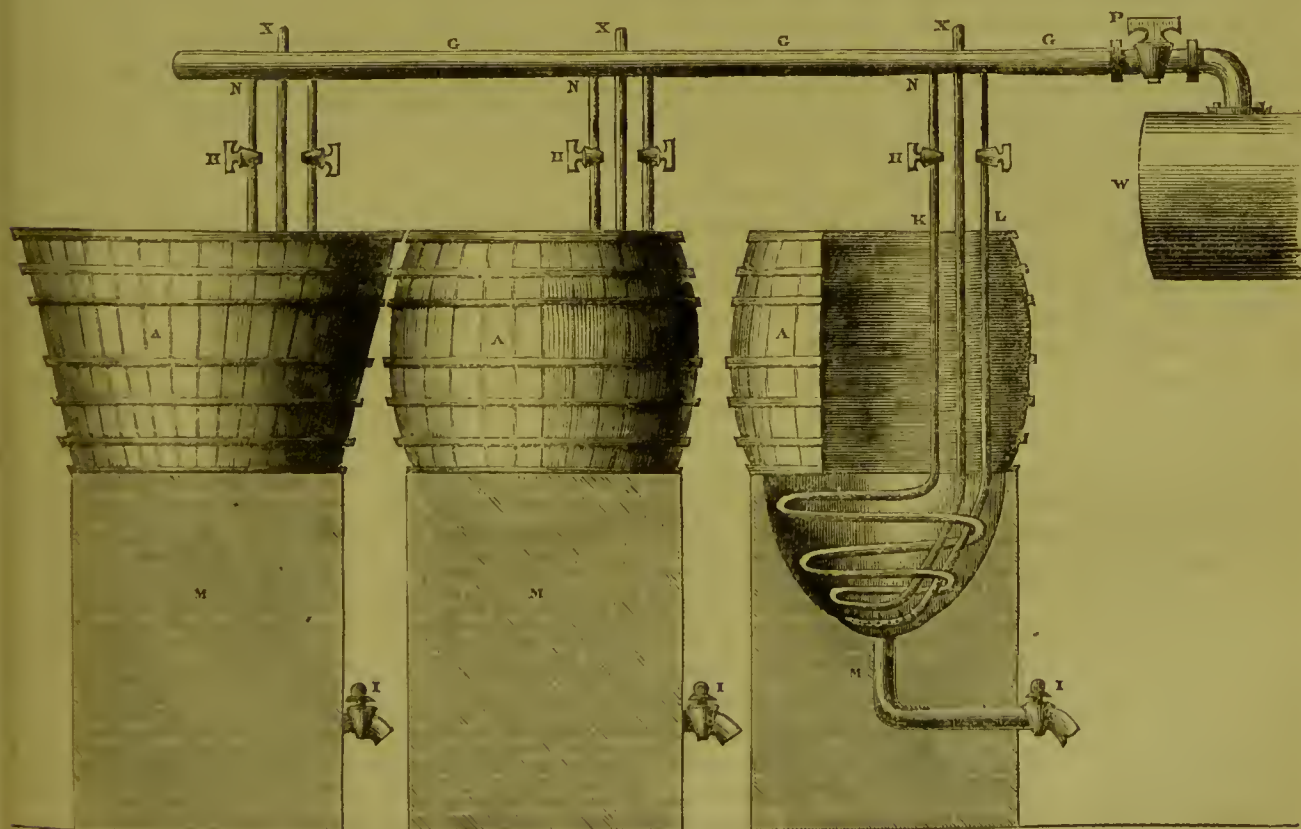
more alkali added. When excess of alkali is present, the milkiness arises either from imperfect saponification, or want of water; the former is known by dissolving a little impure water, which becomes perfectly clear when the whole is saponified.

If the lie contain lime the mixture is also turbid, but the addition of an alkaline carbonate causes the turbidity arising from this cause to disappear instantly. In order to separate the soap from water, free alkali, and glycerin, a large quantity of salt is gradually added to the boiling mass, waiting after each addition till that portion is completely dissolved; the first addition increases the consistency of the mass, while each successive portion renders it more fluid, till it loses its adhesive character, and drops from the spatula in short thick lumps. As soon as the congelation is complete; that is, when gelatinous floeculæ separate from a clear watery liquid, the fire is extinguished, the soap allowed to collect on the surface, and cooled either on the liquid, or ladled out and allowed to get solid. In being separated by means of salt from a very dilute solution, soap suffers an alteration in composition, the soap so thrown down being a bistearate, bimargarate, or binoleate of the alkali, instead of the neutral compound originally in solution; but when the solution is of moderate strength, the soap is separated unaltered in composition. The same results as those obtained by the use of common salt are also produced, although in a less

energetic manner, by chloride of potassium, carbonates of the alkalies, sulphate of soda, acetate of potassa, and chloride of ammonium. Of these, sulphate of soda and chloride of potassium have but a very slight action. Concentrated caustic lies also separate soap from its solution, in the same manner as with common salt; in weak caustic lie, on the contrary, soap is perfectly soluble. On this account soap-boilers, especially at the commencement of the operation, except in the case of cocoa-nut oil, always use weak lies, as the stronger would prevent the necessary amount of contact amongst the ingredients, and very much retard the process of saponification. Not only all foreign matters other than soaps, but also the base of the oils—glycerin—is completely separated from soap by means of caustic or saline solutions, in which it is perfectly soluble. The separation of the small quantities of earthy and metallic soaps, always formed during the process of saponification by means of impure alkalies, requires a distinct operation, termed the *fitting* process, which will be presently alluded to.

The Caldrons.—The boilers or caldrons used in the soap manufacture are formed of cast-iron or wrought-iron plate. Their capacity varies according to the quantity of soap to be produced at each operation. The pan or kettle is fixed in the brickwork, and so built round that the heat acts solely on the bottom. Before the repeal of the soap duty, the waste lies were required

Fig. 502.

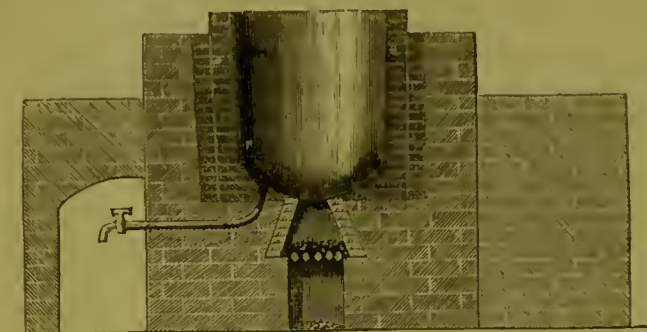


to be pumped out at the top, through the mass of soap. Now it is usual to withdraw these from the bottom, by means of a pipo fixed to the boiler. Fig. 503 is a section of the arrangements. The pans are usually cast with a flange at the upper rim, so that if necessary the boiler may be enlarged by adjusting a hollow cone

of wood, iron bound, and which is termed the *curb*. It may extend as high as desired, and should be surrounded with mason-work as the rest of the pan. In some manufactories the boiling of the soap is accomplished by means of steam, either conducted directly into the materials in the boiler, or when a too high

temperature is not desirable, by applying the steam to the outer surface of the caldron. The application of steam is a method of communicating heat to the caldrons,

Fig. 503.



far preferable to the old method of placing the boiler directly in contact with the fire. Not only is there a great saving of fuel, but less attention, and, consequently, fewer hands are required, while the facility of arresting ebullition at any desired moment is of great importance. In the annexed representation—Fig. 502—are shown three caldrons, A, A, A. The main pipe or feeder, G, is attached to the boiler, W, which is stationary, and generally placed against the wall immediately above the kettles or caldrons. These latter are partly of iron and partly of wood, the upper portion or *curb* being wood, well hooped round by iron rings, and the lower portion of cast-iron, and so shaped that the worm can lie closely to the sides, and that the blow-pipe can fit upon the bottom. The coek, I, is for the withdrawal of the spent lye. The pipe, L, serves when necessary to communicate additional heat to the contents of the pan, and is useful also to agitate the mass. In some manufactories the boiling caldrons are made wholly of wood, well fastened by iron clamps.

MANUFACTURE.—Hard Soaps.—The process of soap-making varies in some particulars according to the kind of oil or grease to be saponified, though the general method is the same for all. The lyes or solutions of caustic soda having been prepared as previously directed, the whole quantity of unctuous material to be saponified at one operation is usually introduced into the boiler at once, and for every ton, from a hundred and fifty to two hundred gallons of caustic liquor of specific gravity $1.090 = 18^\circ$ Twaddell are added, and the whole is gently heated to ebullition. After boiling for an hour and a half or two hours, the whole forms a viscid emulsion, capable of being drawn out into clear threads. The soap now produced is in solution in the water, and requires to be separated before the spent lye can be withdrawn, and to complete the saponification, a fresh one applied. For this purpose a sufficient quantity of common salt is added, which, dissolving in the liquid, causes the soap—which, as previously observed, is quite insoluble in a strong solution of chloride of sodium—to rise to the surface.

When the soap paste has remained in the boiler a sufficient length of time to have become partially cool, it is ladled out into buckets or pails, conveyed to the frame-room, and poured into the frames to solidify. These frames or *scissors* consist of a pile of rectangular inclosures, measuring internally about forty-five inches

by fifteen inches. They should be very smooth, and so jointed as to fit closely together. When piled one upon the other, to the height of three or four feet, they form a tight square well fitted to receive the boiled soap paste. They are tightly bound together by clamps and screw rods. Cast-iron frames, as a substitute for the above, in the manufacture of yellow soaps, are of late introduction. These latter are formed of five rectangular plates, one for the bottom, two for the ends, and two for the sides, so arranged and fastened together as to form a well or reservoir of the same length and breadth as the wooden frames, and about five feet in height. These frames are put together and taken to place much more easily than those of wood, and the good conducting power of the iron considerably accelerates the cooling and solidifying of the soap. If the soap is allowed to solidify in the state in which it is run into the frames, it has a rough granulated texture, and is extremely hard. It is therefore usual to mix a small quantity of water with it in the frame, and afterwards agitate the mixture with a wooden *paddle* or *crut* until nearly cold. By this means it acquires a finer grain, and is not nearly so hard.

The soap having become cold and dry, and in a state to be removed from the frames, which may be known by gentle pressure of the finger making an impression, the iron screw rods which bind the frames together are removed, and each frame is lifted off the soap, which is left a compact mass of the size of the interior of the frame. This mass is then marked round with a kind of iron toothed *scribe* or *dentier*. This instrument is shown in Fig. 504. The teeth are near or distant from each other accordingly as the blocks

Fig. 504.

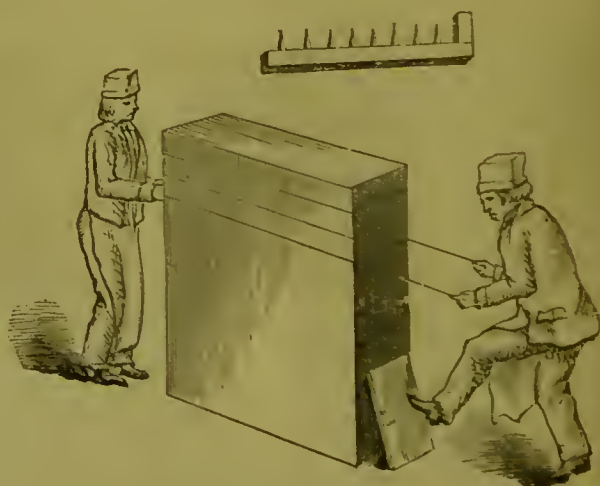


Fig. 505.

are desired of small or large size. The mass is then cut by means of a wire, as shown in Fig. 505, into slabs, and these are again sub-divided into bars. These bars are then removed to the drying-room, and piled upon one another crossways, interstices being left for the circulation of air, to facilitate the drying.

The process of the manufacture of soap, though constant in principle, varies in detail in different countries. The following is the method pursued in the United States, as described by MORFIT:—The strength of

the lie employed differs accordingly as the oil to be saponified is richer in olein or in solid constituent. The operation is commenced by pouring the lie into the boiling caldron to a third of its capacity. This is then heated to ebullition, and the oil is now poured in. The reaction is such that a magma is immediately formed. The proper formation of this magma is considered to be the most delicate and important part of the whole process, and if badly managed, a much greater quantity of lie is required to form the same weight of soap than otherwise would be. After pouring in the oil, the heat is decreased by opening the doors of the furnace, and when the mixture of oil and lie is complete, if necessary a further quantity of weak lie is added gradually, and with constant stirring during the addition, so as to insure thorough contact. The mass should remain homogeneous; the oil should neither rise to the surface nor descend to the bottom. If oil should present itself, it is then necessary to add more strong or weak lie, according to the capacity of the caldron. If the lie is in excess, a further quantity of oil must be added; always stirring briskly upon any addition of new material. The operation requires from eighteen to twenty hours for completion. It may, however, be greatly accelerated by throwing in the scrapings or the waste of soap already made. An excess of soda is recognized by the liquidity and transparency of the paste. If the oil is in excess it rises to the surface. The presence of a large proportion of common salt in the soda, also prevents more or less the proper formation of the magma. When this is the case to any considerable extent, the use of soap scraps is indispensable. The next step in the process is the removal of the large quantity of water which was required for the ample saponification of the fat. This is effected by the addition of lies containing common salt, and afterwards boiling the mixture from fifteen to twenty hours, constantly stirring during ebullition. When the mass opens in different places, the separation is complete. The fire is withdrawn, and the whole is now allowed three or four hours' repose, after which the settled waste lie is drawn off. A further quantity of lie, charged with common salt, is now added, and the mixture is gently boiled; being careful to remove from the sides of the caldron any adhering soap, so that all portions may be in contact with the lie. The mass now acquires more consistence. After some hours' repose, the settled waste lie is again withdrawn. Lie of specific gravity $1.10 = 20^\circ$ Twaddell is poured in, and the mixture is again boiled; by this it acquires a still greater consistence. After continued boiling for about three hours it is allowed to deposit, and the waste lie is again drawn off. This operation is repeated once more, but with strong lies, being careful to stir the paste while being heated, so that the whole may form a homogeneous mass, and allowing only a gentle ebullition. The soap at this stage begins to acquire firmness. The boiling with lie several times successively, serves not only to complete the saponification, but to wash and purify the soap. That it may be perfect, it is necessary to repeat the operation four or five times. As soon as complete, the fire should be withdrawn, and the mass allowed repose to settle and become somewhat cool,

and then ladled out and conveyed in buckets to the frames.

WHITE SOAP—CURD SOAP.—The unctuous material employed in the production of this soap may be tallow or lard, or olive, or well-bleached palm oil, or mixtures of these in almost any proportion. To produce one ton of soap, from ten to fourteen hundredweight of tallow or olive oil are required. The process of saponification is conducted as above described, with but slight variation, attending more particularly to the complete removal of the *alumino-ferruginous* impurities of the lie, which otherwise impart to the soap a coloration more or less intense. Their removal is effected by boiling the soap several times with fresh lies, or by thinning out the soap with a little lie, and applying gentle heat, then covering the caldron carefully and allowing it to settle. The upper strata of soap is afterwards ladled out and run into the cooling frames. The average composition of ordinary white tallow soap is—of alkali one part, of fatty acids about nine parts, and five to eight parts of water. In England by far the greater quantity of curd soap produced is made from tallow or mutton suet and soda only. Some manufacturers, however, substitute for one-fourth of the tallow as much lard or olive oil, and a soap is produced greatly superior in quality, and less liable to change by exposure. Soap made solely of tallow is, besides, inconveniently hard, and very difficult of solution. In France, and on the Continent, when tallow is saponified, olive oil is always added in the proportion of twenty to twenty-five per cent. of the oleaginous material. In England lard is not unfrequently used as the softening agent; and when applied in about the same proportion answers every purpose, while it has the advantage over olive oil, that it does not detract from the whiteness of the soap. The advantages gained by the addition of lard to olive oil or to tallow may be summed up as follows:—The soap remains unaltered for a longer period, does not emit the disagreeable odor of tallow, and the saponification is more perfect, as the excess of olein in the lard or oil compensates for the large amount of stearin in the tallow, thus inducing a more ready and perfect union of the alkali and oily acids. English white or curd soap is largely used by the cloth manufacturers of Yorkshire, and the lace and stocking bleachers of Nottingham. Tallow is not saponified to a very considerable extent on the continent; but in its stead, olive oil mixed with about one-fifth of rape oil is used in the manufacture of hard soaps. This addition of rape oil is always resorted to, because olive oil alone yields a soap as hard and compact, and as difficultly soluble, as soap made wholly of tallow and alkali. This, however, is not the case with rape oil, and other oils of a similar nature—that is, such oils as become thick and viscid by exposure; experience having demonstrated, though the reason is as yet unknown, that the oils which turn viscid the soonest by exposure, yield with soda softer soaps than those made with oils which, like olive oil, remain long limpid under the influence of the air. The admixture of rape oil with olive oil has therefore the effect of modifying the degree of hardness of the soap, just as when lard is saponified in conjunction with tallow.

YELLOW SOAP.—This variety of soap differs from the preceding and other kinds, inasmuch as a considerable quantity of *resin* enters into its constitution. This substance, as previously observed, is capable of entering into combination with the alkalies, to produce a detergent compound soluble in water. Besides the resin, or common fat, or inferior tallow, palm oil is also used to a considerable extent. The usual proportion of palm oil and resin are three and a half parts of the former to one of the latter; sometimes the proportion of resin is still greater, and the soap produced is then soft and dark colored. When the saponification of the oil is nearly complete—that is, at the last charge of the lie—the resin is introduced in a state of coarse powder, and well mixed with the soap by agitation. The mixture is then boiled for some hours; a small quantity of lie being added from time to time, if necessary, to preserve an excess of alkali until the soap is completely formed, when the lie may be withdrawn and one or two waters, or else weak lies, applied successively with agitation for the purpose of washing and purifying the soap. The resinous scum being removed for another operation, the soap is conveyed to the iron frames to solidify. Yellow soap usually contains, to one part of soda, from ten to eleven parts of oily acid and resin, with from twenty-four to fifty per cent. of water. If it contain a large proportion of water, it has just the same appearance as when it contains only a small proportion. When anything like fifty per cent. is present, it has been added while the soap was in the frames, for the purpose of fraud. If tallow or other grease be employed in the manufacture of yellow soap, instead of palm oil, the following is the mode of procedure:—Two thousand pounds of the oil or fat, six hundred pounds of resin, and from a hundred and fifty to a hundred and seventy-five gallons of soda lie of specific gravity 1.075 to 1.150 = 15° to 30° Twaddell, are run into the boiler, and when the whole is melted, the mixture is heated to ebullition, stirring carefully all the time to prevent the resin adhering to the bottom and sides of the caldron. Should the mass begin to swell out, the heat must be decreased. The first boiling should be continued not more than two or three hours, on account of the facility with which the combination of the fat and alkali is effected. After six hours' repose the exhausted lie is withdrawn, and fresh substituted, and the whole is again boiled for three hours or more. After another repose of six hours, again draw off the spent lie, and renew it with fresh. The ebullitions are thus continued, day after day, until the soap has acquired a proper consistence, which may be ascertained by taking a small portion, and when cool, squeezing it between the thumb and finger. If hard thin scales are formed, it is finished, and after having boiled briskly the fire is removed; but if greasy, clammy, and soft, it is not perfect, and it is necessary to add more lie and reboil. The soap is now to be cooled by adding three bucketfuls of lie, and after two hours the liquor is withdrawn. Six or eight bucketfuls of water are now added, and the whole is again briskly boiled, stirring constantly until the soap is melted. A little of the boiling paste is now removed on a wooden spatula, and if it run clear from the lie,

more water is added, and the boiling is continued. If it should not run, too much water has already been added, and a half pailful of strong solution of salt must be thrown in.

The most delicate part of the operation is that of boiling, and it therefore requires particular attention. That it may be complete, the soap should, when a portion is taken on a spatula, and the latter is held in an oblique position, shake and disperse tremulously, as would a body of gelatinous consistence. Then the lie may be withdrawn, and the soap considered as finished. In France yellow soap is produced by a similar process as the other kinds of common soap, adding at the commencement of the operation fifteen to twenty per cent. of resin. Some manufacturers make a soap with but five to ten per cent. of resin, and this being lower priced than soap made entirely of grease, has a more extensive sale, and is preferred especially for domestic purposes. By its property of dissolving more readily in sea-water than other soaps, it is also well adapted for use on shipboard. The common brown soap is made as the preceding, but by using a greater proportion of resin, and substituting for the tallow, either in whole or in part, the common kinds of grease, such as soap fat, bone fat, *et cetera*.

MOTTLED SOAP—MARBLED SOAP.—In the manufacture of this variety of soap, the same kinds of materials are used as for white soap, and its different appearance arises from the different mode of treatment of the soap, after the completion of saponification. By a reference to the general process of soap-making given above, it will be observed that even after the complete formation of soaps, that is, when the whole of the oil or fat used is decomposed, and the oily acids have entered into combination with alkali, the soap still requires further treatment before it is brought into a marketable condition. It exists now in the form of immovable globules, and it is necessary to cause these to coalesce into a homogeneous mass. This is effected by a process termed *fitting*, which consists in the fusion of the contents of the boiling caldron in a weak lie, or in water, and afterwards boiling the whole for a longer or shorter period, according to the kind of material operated upon, the mass being prevented from boiling out of the copper by dashing shovels into it, so as to break the froth and favor evaporation. During this process in making white or curd soap, the more or less colored impurities of the materials termed *nigre* or *nigger* fall to the bottom; but in making mottled soap, the mixture is left in a thick or viscid state, so that the impurities cannot subside, and is transferred to the frames in this condition. To produce a good marbled soap, it is necessary that this latter operation be very carefully conducted: as, if too great a quantity of liquid be added, or if the mixture of soap and water or weak lie cools too slowly, all the coloring matter falls to the bottom, leaving the upper stratum of soap perfectly white, while, on the other hand, if it becomes too quickly cold, the soap remains in the granular condition. THÉNARD compares the separation of the coloring material to a kind of crystallization, and MORRIS ascribes the result to the formation of an *alumino-ferruginous soap*, and the lesser solubility of this at a lower temperature. The

lower veins in mottled soap appear to be due to the presence of an exceedingly minute trace of sulphide of iron, derived from the last service of lie, in which it exists in solution as a double sulphide of sodium and iron. As a perfectly colorless lie, apparently free from every trace of iron, will produce mottling if allowed to separate slowly from soap, it has been questioned whether iron is really the coloring agent; but, as noticed by PARNELL, this seems to be proved from the fact that the ash which remains after the calcination of the brown parts of such soap, affords to reagents a sensibly larger quantity of iron than the white parts of the same sample of soap. Granting that the lie used may be free from iron, which, however, is very rarely the case if an alkaline sulphide be present, this has a solvent action on metallic iron, and will therefore take iron from the pans or boilers used; and even supposing the lie to be free from alkaline sulphide, it becomes a matter of doubt whether, in the process of boiling, a portion of sulphate may not be reduced to the state of sulphide by prolonged contact with the organic matter. In some cases—and in such, iron must be present in some form or other—the mottling is produced, or at least the proportion is increased by sprinkling on the surface of the soap, after being boiled with the last service of lie, a small quantity of very strong sulphuretted lie, which produces the mottling by filtering slowly through the mass of soap. At Marseilles and other places where olive oil is used in making soap, a quantity of sulphate of iron is added; in which case the mottling is produced, both by the black sulphide of iron, and by the oxide of iron—the red portion—which latter combines with fatty acids, producing a true ferruginous soap. The quantity of copperas requisite is about eighteen ounces to four hundred and fifty pounds of oil or fat. It is added first mixed with weak lie, and should be poured in during the coction of the soap, and before it has acquired too much consistence. When the soap is ladled out of the boiler, it is of a uniform slate tint; but as it becomes cool, the metallic portion separates into nodules, and by the trickling of the excess of lie through the mass, they assume those forms to which the term *mottled* is applied. By varying the proportion of sulphate of iron a tint is produced of a lighter or darker hue. Soaps containing this have exteriorly a rusty color, owing to the sesquioxidation of the iron at the expense of atmospheric oxygen, and this shade may be deepened by the addition of venetian red, or colcothar, into the particular tint to which the French apply technically a term signifying *hidden red*, and which upon the deep blue produces the appearance of marble, as seen in the variety known as *castile soap*. This peculiar tint may be communicated as well before as after the true marbling; for which purpose it is necessary to thin out the colcothar with water, and in adding it to incorporate it well with the soap. Generally, in the preparation of mottled soap, less care is exerted in the choice of materials than for white soaps, and the heterogeneous mixture of fatty substances, known as *kitchen stuff*, usually forms one of the materials.

COCOA-NUT OIL SOAP.—Cocoa-nut oil is very easy to saponify, and is used to a considerable extent in

the manufacture of white soap, as well *per se*, as in admixture with other oils and fatty matters. The disagreeable odor of this oil is removed most effectually and conveniently by boiling in a wooden vessel by means of steam, with a mixture of six pounds of sulphuric and twelve of hydrochloric acid to each tun of oil. The oil so purified is heated in the boiling caldron, with the addition of a portion of olive or some other readily saponifiable oil or fat, and the soda lies are gradually introduced in the usual manner. Towards the conclusion of the process of saponification, a quantity of caustic potassa lie is thrown in, and the boiling is continued as long as may be necessary. The soap thus formed requires, for its separation from the lies, a much larger proportion of salt or other saline matter, than the soaps formed of tallow, palm oil, or olive oil. Otherwise the process of separation is the same as for other soaps. Pure cocoa-nut oil soap, by the usual method of saponification, can only be obtained by the use of a very large quantity of common salt, and then contains so very little water, or is so extremely hard, that it cannot be cut with a knife. On this account the usual mode of proceeding is not followed in the production of this soap. The principal distinction between cocoa-nut oil and other oils and fats is, that while the latter are most readily saponified by weak lies, cocoa-nut oil is quite unacted upon until the lies have obtained a considerably higher degree of concentration; saponification then suddenly commences, and proceeds with extraordinary rapidity. Only the strongest soda lies are employed in the production of this soap, and by taking pure and perfectly caustic lie, the use of salt in purifying the soap is dispensed with. Pure cocoa-nut oil hardens much too quickly to exhibit any distinct formation of curd, and is consequently incapable of marbling of itself; it is very white, translucent, exceedingly light, and forms a good lather, but has always a more or less offensive smell.

An important property of cocoa-nut oil is its power of combining with more water than can even be incorporated with tallow soap, and this property frequently leads to dishonest practices. Cocoa-nut oil actually produces no greater quantity of soap than an equal weight of tallow; but the soap from the former can easily be made to absorb one-third more water or lie, and, at the same time, exhibit no want of consistence or softness, as would be the case with other soaps. The more rancid cocoa-nut oil be, the more readily is it saponified.

As previously remarked, cocoa-nut oil is not usually saponified alone, but is added to other oils for the purpose of producing quickly solidifying soaps containing a large proportion of water. When equal parts of cocoa-nut oil and tallow are used, the soap has the smell of common tallow soap. The boiling is continued until a specimen exhibits the proper consistence under the thumb. Tallow itself could not be saponified under the same conditions; but the saponification begins with the cocoa-nut oil, and the tallow is then saponified by means of the presence of the cocoa-nut oil soap. The different varieties of this soap are marbled artificially. The blue or red coloring matter is rubbed up with a little of the soap, or better, with a separate portion

of good cocoa-nut oil soap, until the whole acquires a red or blue color. This is then placed in alternate layers with the colorless soap; and by stirring the mass together streaks and veins are produced in all directions.

MARSEILLES SOAP.—This variety of soap is produced by the saponification of olive oil alone. The process does not materially differ from that described for white soap. The duration of the operation is longer or shorter according to the quality of the oil. Some manufacturers use, in the fabrication of this soap, a certain proportion of poppy oil with the olive oil; and the addition is rather beneficial than otherwise, as the soap produced is less hard, and consequently more easily applicable to detergent purposes. It is at present manufactured on a considerable scale in this country.

An improvement on the old method of soap-making was invented by DUNN, and has been already alluded to. It consists in the application of streams of air to the materials, whilst in the course of saponification. The air is forced below their surface by means of a pump; and the saponification is said to be greatly accelerated, and the process otherwise much improved. The following is the method as stated by MORFIT:—Into each of the ordinary boiling caldrons a circular ring of pipe of about one and a half inch bore, and perforated with small holes, is fixed in the well of the kettle, just below the flange or joint, keeping it sufficiently off the bottom to allow a stirrer to be used to scrape the bottom when necessary. The pipe is supplied with atmospheric air from a cylinder blast, or other suitable forcing apparatus, and is connected with the latter by means of a pipe attached thereto, and rising up to the top of the kettle, where it is furnished with a stopcock and union-joint, for the purpose of connecting or disconnecting the parts of the pipe within and without the copper. For a clean yellow soap ninety gallons of lie of specific gravity $1.14 = 28^{\circ}$ Twaddell, are run into the caldron. The fire being kindled, the caldron is charged with two thousand and fifty pounds of grease; and as soon as the lie is at or near the boiling point, the blast is commenced, keeping up a brisk fire so as to continue the materials in the kettle as near ebullition as possible. When the lies are exhausted, an additional quantity is gradually added until the grease, oil, or fatty matter is taken up. Five hundred and fifty pounds of resin are then added—a bucketful at a time, with more lie occasionally, until three hundred gallons of the strength above-mentioned have been used, keeping the blast in action the whole time, and the contents of the kettle as nearly boiling as possible. When the whole of the resin is melted, and thoroughly incorporated with the saponaceous mass, and the strength of the lies taken up, the blast should be stopped, and the contents of the boiler briskly boiled, and then allowed to rest, that the spent lies may separate and deposit. These being now drawn off, the soap is then brought to strength by fresh lies as in the ordinary process of soap-boiling. During the operation of the blast, the soap must be kept in an *open* or *grained* state; and for this purpose salt or brine is to be added when necessary. Experience has shown that it is better not to make a change of lie during the operation of the blast, when lie of the

strength above-mentioned is used; but if weaker lie is employed, one or more changes may be made. It is found desirable, also, that the soap should be kept in a *weak* state during the passage of the streams of air through the materials; otherwise it is apt to swell up, from the air hanging in the grain; and this is found troublesome to remove, requiring long boiling. If dark-colored materials are used, it is well to keep the blast in operation three or four hours after the soap is melted; provided the soapy mass is kept *weak* and *open* or *grained*.

Another improvement in the manufacture of soap was invented by Mr. ANDERSON, by means of which the soaps are more completely purified. This is described by MORFIT as follows:—In the manufacture of yellow or resin soap, the ordinary process is that of boiling the materials upon successive portions of alkaline lie until they become *strength*; that is, until the oily matter is perfectly saponified, after which the curd so produced is subjected to a purifying operation termed *fittig*, performed as follows:—The lie used in boiling to strength is carefully pumped off from the soapy paste; and the latter is diluted with weak lie or water, and boiled to the proper consistence. After two days' repose the lies settle out of the perfect soap, and there is found below the latter an inferior or second quality of soap termed *nigre* or *nigger*. The perfect soap is cleansed or lifted off carefully from this, and transferred to the cooling frames; the mass of imperfect soap either being added to the next charge, or concocted into an inferior soap. The process followed in making curd soap, is to boil the materials upon successive lies until they become saponified; after which, and when the curd is of proper consistence, it is removed carefully to the cooling frames without further treatment. The invention of Mr. ANDERSON, it will be observed, does not interfere with the usual mode of producing the soap, but refers only to its purification, and begins at that point where the materials having been properly saponified, the soap *ribbons out* well on the finger. At this stage, instead of boiling out the head, and finishing as heretofore practised, the new process is commenced by pumping out or drawing off the strong lie on which the materials have been boiled, and then adding weak lie or water in successive portions, and boiling the whole until the mass assumes a proper appearance for *fittig*. The whole is now allowed to stand at rest for from twenty-four to forty-eight hours, or until the *nigger* or imperfect portion of the soap is deposited. This latter may then be separated, either by pumping it off from under the purified compound into an adjacent kettle, or by removing carefully the upper stratum of purified soap by means of ladles or buckets.

Whichever method be pursued, the cleansed material must now be treated with the proper finishing lie for curd soap; which being added, the whole is boiled until the soap becomes of sufficient consistence to be transferred to the cooling frames. When the materials employed in the production of this soap are very impure, the *fittig* or purifying process as above described is repeated one or more times; in which case after the first separation of the imperfect soap,

the remaining partially-purified material is treated with a lie only of moderate strength, instead of the ordinary finishing lie, and the whole is boiled with weak lie or water until sufficiently diluted to allow the proper performance of the fitting process; after which, time is allowed for deposition, the imperfect soap is again removed, and after the addition of the finishing lie, the remainder is boiled to a curd as before. The further treatment of the separated *nigger* or imperfect soap and its conversion into mottled soap, is effected by adding to it in an ordinary caldron the usual finishing lie for a mottled soap, and boiling until it is of proper consistence to be removed to the frames. The quantity obtained from one charge of soap by the fitting or purifying process, is not enough to be conveniently boiled by itself; it is therefore set aside, and six or more batches operated upon at one time.

SOFT SOAP.—This variety of soap differs in many essential particulars from those already described. The alkali used in its production is potassa exclusively, and the oil, either in whole or in part, a drying oil, as that of hemp seed, poppies, *et cetera*, or fish oil, as whale or seal oil. The theory of the reaction of potassa upon fats and oils is precisely the same as in the case of soda. Soaps with potassa base are, however, manufactured on an entirely different system to those of soda or hard soaps. In the latter, the soap is withdrawn from the lie when only a portion of the oil has been saponified, and fresh lies are added until saponification is complete.

In the production of potassa or soft soaps, no lies are separated during the whole course of operation; the only object being the combination of the potassa with the fat or oil. Potassa soap, therefore, of course contains the whole of the base of the oils or glycerin, which is expelled from combination by the stronger base, as well as the impurities always existing in the lie, as carbonate of and caustic potassa, chloride of potassium, sulphate of potassa, and in small quantities, many other salts, which in the manufacture of hard soaps are removed in the exhausted lies. Potassa soap, also, always contains a much greater proportion of water than hard soaps, the quantity being in the majority of instances from fifty to sixty per cent. If desired, the glycerin of the fat and saline impurities of the lie might easily be removed by the application of strong lies towards the completion of the process, but on the large scale such a system is never pursued. A much larger proportion of alkali is consumed by a given weight of oil or fat, when saponified by potassa, than when soda is used, one part of pure potassa being taken up by from four and a half to five parts of oil; and hence the quantity of real soap produced from a given weight of oil or fat when saponified by potassa is considerably greater than when the alkali used is soda; and this quantity is still further augmented by the large proportion of water, together with the glycerin and saline impurities always contained in the lies, and which, as above stated, are not removed from the soap. From the great analogy which exists between soda and potassa compounds, it would be expected that potassa soap would be separated from its solutions by chloride of potassium, as soda soap is by chloride of sodium. This, however, is not the case, as when to a solution of potassa soap, procured

by treating oils or fats with caustic potassa lies, a considerable quantity of chloride of potassium is added, no separation of soap takes place; the salt dissolves in the soapy mixture, and the solution remains clear. Potassa soap can only be separated from the lies and eliminated glycerin by adding strong potassa lies after the soap is complete, and the excess of alkali and the glycerin may then be allowed to subside, and subsequently be more completely removed by placing the soap to drain. On the large scale, however, as before observed, soft soap is never separated as above; the soap solution is boiled down until homogeneous and of a proper pasty consistence.

The process of manufacture of soft soap is as follows; the proportions of oil and lie being regulated according to the strength of the latter, and the qualities operated upon at once varying with the greater or less capacity of the boiling caldron. According to MORFIT, whose extensive experience in the soap manufacture renders his remarks of great value, the larger the caldron the better and more economical. To be properly proportional, the diameter should always be greater than their depth, and should be only half filled with material, as the soap when boiling swells up and rises considerably. In some soaperies the whole of the oil and tallow is introduced at once, together with a portion of the lie, and the remainder of the lie is added after some hours' ebullition; in others, both the oil and lie are introduced gradually. The lie should, indeed, always be gradually added, and in small quantities at a time, spreading it superficially over the whole mass. As soon as the two clear liquids, separately introduced, unite together, the whole becomes much thicker, and in some cases boils quietly, but in others swells up into froth. In the latter case it must be thrashed with a stirring pole, and dosed with a sufficient quantity of lie to lessen the commotion and prevent loss of the material by running over. The caldron requires to be constantly watched while over the fire. If too much lie is added at the commencement, no union is effected between the oil and the alkali; and if the lies are too strong they seize on the oil too rapidly, and instead of becoming thick and viscid, the mass becomes clotted. This latter inconvenience may be remedied by adding lies of a lower degree of strength. If the lies are not sufficiently strong, combination ensues so tardily that part of the superabundant water must first be expelled by evaporation before a perfect union between the oil and alkali can be effected. When combination is perfect and the great foamings have subsided, the pasty mass should become clear and transparent, and free from clots or granules, and no acrid taste should be perceptible. To ascertain if this be the case, a small sample is taken out and cooled. If it should not be of proper consistence and free from opacity, the boiling is continued, and after some time another sample is taken, and so on until the soap is properly finished. If the test sample thickens on cooling, has a brown color, is perfectly homogeneous, and is not ropy when worked between the fingers, the soap is finished, and the fire should at once be withdrawn. A fair criterion of the quality of the soap is said to be furnished by a peculiar phenomenon observable during its cooling; a little opaque zone forming around the test-portion taken

from the caldron for an assay, indicates perfect saponification, and is called *strength*, the absence of which denotes a deficiency in strength; and when the zone vanishes soon after having made its appearance, the soap is said to have *false strength*. When it comes in the best form the soap is perfect, and may be secured in that state by removing the fire, and then proceeding as subsequently directed.

To allay the foaming and render the finished soap fit to be transferred to the barrels or casks without endangering its detergent quality or diminishing its causticity, the soap should be cooled as rapidly as possible. For this purpose a quantity of ready-made soap—a ton or more, according to the size of the caldron—is added to the hot mass. This, in melting, rapidly abstracts a portion of the heat of the recently made soap, until the degree of that and its own is uniform. The foaming having subsided, the soap is racked off into the barrels, in which it is sent away. In the manufacture of soft soap MORFIT observes, that it is better that the boiling should be too much than too little protracted. Soap which is not sufficiently cooked, changes and spoils, while the only disadvantage produced by excessive boiling is a diminution in the quantity of the product. The usual time requisite for a charge is six or seven hours, but varies with the strength of the lies, the temperature of the atmosphere, and other incidental circumstances.

In Great Britain a small proportion of tallow is usually introduced as one of the materials for the production of soft soap. This addition is for the purpose of producing the solid white granulations of stearate of potassa termed *figging*, because the soap then resembles the granular texture of a fig. Hence British soft soap presents the appearance of a brownish transparent body, through which white grains are disseminated. These figged granulations do not usually make their appearance until two or three weeks after the soap has been made, and during the hot summer months they do not appear at all. They are improperly considered to be a proof of the good quality of the soap, and hence the figged appearance has been imitated by the admixture of starch. Messrs. LUND and UNSWORTH of Liverpool are said to be the largest makers of soft soap in England. They generally turn out fifty or sixty tons weekly of a most excellent article.

The Scotch process for manufacturing soft soap is as follows:—Two hundred and seventy three gallons of whale or cod oil, and four hundred pounds of tallow are introduced into the soap pan, together with two hundred and fifty gallons of potassa lie, of such strength that one gallon contains six thousand six hundred grains of real potassa. Heat is now applied to the pan, and as the mixture approaches the boiling temperature, much froth appears, and to prevent boiling over, it is beaten down on the surface. Should it subside quickly into a doughy looking paste, it is an indication that a too strong lie has been used. Its proper appearance is that of a thin glue. There should now be added about forty-two gallons of a stronger lie, equivalent to eight thousand seven hundred grains of potassa per gallon, and after a short interval, an additional forty-two gallons; and thus successively

until nearly a total of six hundred gallons has been introduced. After properly boiling, to complete the saponification of the fats, soap will be obtained amounting in quantity to six thousand four hundred pounds, from the above proportions of materials.

American soft soap, MORFIT states, differs very little from the preceding in its mode of manufacture; two hundred pounds of oil saponified by seventy-two pounds of potassa in lies of specific gravity $1.110 = 22^\circ$ Twadley, yielding four hundred and fifty pounds of finished soap. Fish-oil soft soap has usually a dark-brown color, and that made from refuse fat and oil, a dirty-white color. Soap made with colza oil is slightly bluish. When hempseed oil is used, the soap has a greenish color. The latter is by some consumers preferred to other kinds of soft soap; and hence ordinary soft soap made from fish oil is frequently tinged green by adding a small proportion of powdered indigo, or a solution of indigo in alkali, the yellow of the soap forming a green with the blue of the indigo. Soft soap is always of a pasty consistence, and even if excessively boiled, does not harden, but becomes scorched and dry. In this country it is chiefly used for fulling, and for the scouring and cleansing of woollen stuffs. Being possessed of greater solubility, and having a much more powerfully detergent action, it is also especially applicable for scouring floors and wooden utensils. In Germany, Belgium, and Holland, it is also used for washing linen, which thereby acquires a most disagreeable odor of oil. When chloride of sodium is added to soft or potassa soap, decomposition ensues, the chlorine of the salt seizes the potassium of the soap producing chloride of potassium; and at the same time, the sodium takes the place of the potassium in the soap, and a hard or soda soap results. The proportions recommended by PELLETIER and others for the conversion of soft into hard soaps, by means of the above-mentioned decomposition, are six pounds of salt to every three pounds of oil, and the solution of the salt in water is to be added in small portions and gradually to the soap, the latter being in a state of ebullition. The soda soap produced separates quickly from the lie, and the operation is terminated in the usual way. This process for producing hard soap is of great importance in those countries where soda is not to be procured, as potassa and its salts may be substituted for the latter in the process of saponification.

SILICATED SOAPS.—Many varieties of soap are met with in commerce termed silicated soaps. They are produced either by the addition of silica itself or an alkaline silicate to the soap paste, just before cooling and solidification. Under this title are included also those soaps admixed with pipe-clay, and matters of a similar nature, which, though not strictly silica soaps, are usually classed with them. Sand soaps differ from silica soaps inasmuch as in the latter the admixture has been prepared artificially, while in the former common white sand is the silicious ingredient, and the only preparation it has undergone is finely sifting. In the preparation of sand soap, the finely-sifted sand is added to ordinary white soap and thoroughly incorporated with it while in the pasty condition, in the proportion of seven or eight per cent; and as soon as the mass has

cooled, it is taken from the frame and cut into tablets or moulded into balls. Of the three silicated soaps, the first that claims mention is that prepared by Mr. GOSSAGE's patent process. It consists in the introduction into soaps prepared from fatty or resinous materials of a highly concentrated solution of silicate of alkali. The process for the preparation of this silicate, termed also *soluble glass*, is described in the specification as follows:—When soda is used as the alkaline solution to be combined with silica, nine parts of soda ash are mixed with eleven parts of clear sand, and the mixture is to be fused in a reverberatory furnace, provided with a tap-hole through which to allow the finished product to run off. Sufficient heat is to be applied to the mixture, stirring from time to time until combination has been effected; the product is then drawn, and received either in metallic moulds, or in moulds formed of damp or moistened sand. The charge for a furnace having a bed or sole measuring sixty square feet, is about a ton of the mixed sand and alkali, and each charge requires four or five hours to be properly fused and combined. For the preparation of silicate of potassa the proportions are equal weights of crude carbonate of potassa and sand, and these are melted exactly as in the production of silicate of soda. It is always desirable to use such proportions of alkali and sand for the production of the silicate, that the latter may be almost wholly soluble in water; when the alkali is deficient, however, this is not the case, and to obtain perfect solution, it is necessary to use as the solvent a solution of caustic soda or potassa.

The solution of the perfect silicate may be effected simply by grinding the latter to powder, and agitating this in a pan containing boiling water; but a much preferable method of solving is, by the employment of an apparatus consisting of a vessel formed of iron plates, or other suitable materials, which vessel is fitted with a perforated diaphragm or false bottom placed about mid-way between top and bottom. The silicate, first broken into small lumps, is placed upon the false bottom, and hot water is introduced into the vessel to a sufficient height to cover the pieces of glass to be dissolved. Steam is then introduced into the water so as to maintain the latter at a high temperature.

As the glass dissolves, it communicates additional gravity to the water, and the heavier solution descends in the vessel whilst the lighter fluid rises, and coming in contact with the glass also dissolves it, and acquiring density again descends. In this manner a continued circulation of the fluid takes place, and the glass becomes nearly all dissolved, yielding a strong solution.

After allowing undissolved matters to deposit, the solution is transferred to a cast-iron evaporating pan, and by the application of heat concentrated until of specific gravity 1.450, when it becomes viscous on cooling, and is then in a condition to be added to the soap. When the solution of the silica is to be added to a soda soap, the latter, prepared in the usual manner, is to be transferred from the caldron into a tub or pan, termed the mixing vessel, capable of containing about fourteen hundredweight of soap, and the viscous solution of silicate of soda is to be added in such proportions as to yield the particular quality of soap

desired to be produced; and the mixture is then well agitated by means of crutches or paddles. The soap and the viscous solution should be each at such a degree of heat that the mixture, when formed, may be at a temperature of 160°, and the agitation is to be continued until the temperature is reduced ten degrees, that is, to about 150°. The mixture is then transferred to the cooling frames, and agitated therein by means of crutches, until it becomes of such consistence as to render its continuance no longer practicable.

Although the mixture of the solution of silica with the soap may be effected by means of crutches worked by hand, as above described, it may be stated that when a more rapid agitation is applied than can be effected by this means, the soap produced is a more perfect mixture, and of more uniform quality.

For admixture with soft soap, the soluble glass is formed by the fusion of a mixture of sand and potassa, as previously mentioned, for the preparation of a silicate of potassa. This is dissolved, and after concentrating the solution to the viscous condition, it is mixed with the soft soap, exactly as described in the case of soda or hard soaps. As the proportional amount of alkali contained in a mixture of soap with soluble glass is greater than that contained in the unmixed soap—if it is desired to reduce this amount, as the excess of alkali may be injurious for some purposes to which the soap may be applied, it is effected by the addition to the solution of the silicate of sulphuric or hydrochloric acid, previously to its reduction to the viscous condition. The mixed silicated soaps may be obtained of any requisite degree of hardness by the greater or less concentration of the solution of soluble glass. The compound soaps produced by the above process, the patentee states, are possessed of valuable detergent properties, independently of the real soap contained in them.

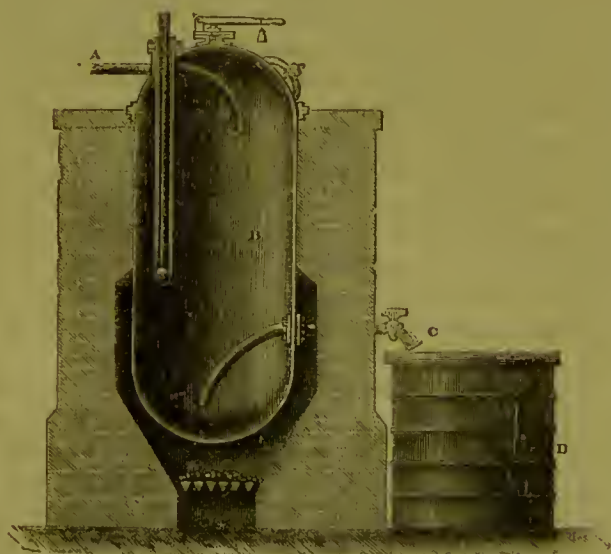
In the process invented by Mr. SHERIDAN for the preparation of silicated soap, either calcined flint, or quartz, or sand is used for the production of soluble glass. If sand is the silicious ingredient, he directs that it be mixed with carbonate of soda in the proportion of one part of sand to three of soda, and the mixture is then to be calcined to fusion in a reverberatory furnace. The product of calcination is drawn out into water and dissolved by the aid of heat. Thus far the process resembles that of Mr. GOSSAGE. Mr. SHERIDAN, however, now directs that a current of carbonic acid be passed through the solution of silicate of soda, whereby the silica is displaced from combination and precipitated in a gelatinous form. From this the liquid containing the soda, reconverted to the state of carbonate, is withdrawn, and evaporated to dryness for use again; the precipitated silica is mixed with caustic soda or potassa of specific gravity 1.1515 = 30° Twaddell, and boiled for eight hours, with constant stirring, until it becomes a homogeneous mass. This latter part of the process seems a very useless operation. It is simply the destruction of a compound already in the liquid condition, and its reproduction in exactly the same state, but by another and more objectionable mode of treatment—objectionable because combination between silica and an alkali is effected

much more easily and perfectly by fusion than by ebullition of the materials together with water. When the silicious ingredient is flint or quartz, the calcined material is to be reduced to nearly an impalpable powder by wet grinding with horizontal stones. The powder obtained is thinned out with about twenty per cent. of water, and then boiled with caustic soda lies of the strength above mentioned, for eight hours, or until it becomes a homogeneous mass. In this condition, in which it is technically termed *detergent mixture*, it is ready to be mixed with the soap paste.

A method for the preparation of silicated soap was also invented by Mr. DUNN, in which either silica itself, or an alkaline silicate, is made to unite with soap under steam pressure. According to the author of this process, the method is also applicable to the manufacture of soap even when silica is not an ingredient, with the advantage over the usual mode of boiling, of effecting a more perfect union of the ingredients in a shorter time, with greater economy, and at a diminution of expense.

The apparatus employed is represented in section, Fig. 506. The boiler, B, should be furnished with a

Fig. 506.



man-hole, safety valve, a thermometer plunged into a mercury chamber, and all the ordinary appendages of such an apparatus. A is the feed-pipe, and c the pipe through which to discharge the finished product. The crushed flint or quartz to be combined with the soap is mixed with caustic soda or potassa lie, in the proportion of one hundredweight of silica to one hundred gallons of lie of specific gravity $1.16 = 32^\circ$ Twaddell, and introduced into the steam-tight boiler. The fire is then kindled, the valve being so regulated as to allow the temperature of the materials to rise gradually to about 310° , or at a pressure of fifty to seventy pounds to the square inch. When it has remained at this temperature for about three or four hours, the contents are discharged and cooled down. The solution of silicate of potassa or soda thus obtained, according to the kind of alkali used, is added in the proper proportion to the soap paste, either in the caldron or frame after the saponification is complete, and before the soap is become cold.

SULPHATED SOAP.—The variety known to manufacturers and in commerce as sulphated soap is produced by a process patented by Dr. NORMAN. The object of the patent appears to be, to enable manufacturers to produce a soap from inferior oils and fats possessed of detergent properties, and also of a hardness equal to that from oleaginous bodies of much higher value. The great objection to soap made from the inferior kind of fats, and also to soap containing more than a due proportion of resin, is their very ready solubility in water, in consequence of which great waste is always experienced when these soaps are used for washing or cleansing purposes. By Dr. NORMAN'S process, a soap is obtained from the cheaper oils possessed of equal detergent properties, and also of an equal degree of hardness, to that obtained by the employment of the more valuable fats and oils; thus rendering a large class of oleaginous bodies available in soap-making, to which purpose they were previously applicable. The following, extracted from the specification of the patent, will render the process sufficiently intelligible.

When the soap is made in the usual manner, and is ready to be cleansed, there is to be introduced and crutched into it a certain quantity of neutral anhydrous sulphate of soda, or of neutral sulphite of soda, or of the two salts conjointly. These salts have the property of imparting to soap made with more than the usual proportion of resin, or with those kinds of fat or grease known as *weak goods*, a greater degree of hardness than they would otherwise possess; and of rendering such soaps generally of a paler color, thus enabling them to retain their weight better than would be the case without such addition. The soap containing sulphite of soda has, in addition, the property of removing from textile fabrics and fibrous substances the chlorine which they are apt to retain after bleaching. The mode of procedure with the sulphate of soda or salt cake, is as follows:—

The salt is to be treated with a quantity of hot water, less than is necessary to dissolve the whole of it, and to the saturated solution thus obtained as much solution of caustic or carbonate of alkali is added as is necessary to impart to the liquid a faint alkaline reaction. This addition is made not only to saturate any free acids that may be present, but also to remove the sesquioxide of iron always contained in crude salt cake, and which, by this treatment, will be precipitated. When this precipitate has completely subsided, and the supernatant liquor is perfectly clear, as much of the latter is added to the soap paste as is necessary to confer upon it the requisite degree of hardness when cold; the particular quantity varying according to the nature of the fat or oil saponified, or to the proportion of resin present. The mixture of salt-cake solution and of soap are to be thoroughly incorporated by stirring or crutching, continuing the agitation until the mass has become so hard that the stirring can be no longer practised. When the sulphite of soda is used, the patentee recommends that it be dissolved in as little hot water as is necessary for the purpose; and the solution is added to the soap exactly as above described for the sulphate of the same base, or salt

cake. If the salt be a bisulphite of soda, or if it is not in a state of purity—in other words, if it contain an excess of sulphurous acid, or be contaminated by oxide of iron—the excess of acid should be neutralized, by adding to the solution of the salt as much carbonate of or caustic soda as will impart a slight alkaline reaction; and after allowing the separated matters to deposit, the clear supernatant liquor is to be introduced and crutched into the soap, precisely as directed above in reference to the salt cake. The usefulness of this invention has been tested and carefully examined by several eminent chemists, among others by HOFMANN, MILLER, and URE, all of whom speak in high terms of its merits; and the Editor is gratified to have this opportunity to add his testimony as to the value of an invention the object of which is to supply a cheap soap as economical to the consumer as that produced by the more expensive fats and oils.

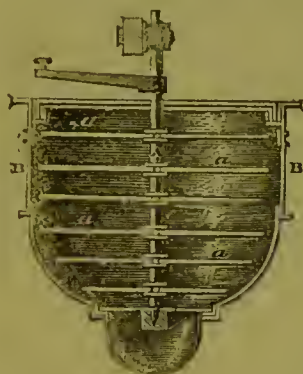
SNELL'S DEXTRIN SOAP.—This soap contains, in a state of admixture, a greater or less amount of vegetal matter, obtained from either potatoes or other sources. It is termed by the inventor dextrin soap; as prepared, however, according to his directions, no dextrin enters into its constitution, but, instead of this, woody fibre and unaltered starch. The method of preparation is said to be preferable to the old plan of combining farina with alum and soda in the manufacture of soap, inasmuch as it insures the perfect incorporation of the admixture with the saponified fats and oils, whereas, when they are previously acted upon by alum and soda, their tendency to union is partially impaired. The vegetal matter used by the inventor is obtained from potatoes as follows:—The washed potatoes are reduced to as fine a pulp as possible, by a revolving cylinder furnished with parallel plates of steel or iron. These plates have fine teeth like saws, the teeth rising just above the surface of the cylinder under a hopper, which receives the potatoes. The pulp falls on sieves or screws below, and passes over the upper sieve. This is a plane of five feet in breadth and eight in length, with one or two bars crosswise, covered with a wire-cloth of thirty holes to the inch. At the top, and about midway down the sieve, are pipes containing water, so arranged that the water shall run from the pipes through small holes the whole breadth of the sieve, the finer parts of the potatoes running through the meshes of the sieve into a vat. The finer parts, termed dextrin by the inventor, which fall on a wooden plane placed under the second sieve, but in a contrary direction thereto, are received in vats, where they are repeatedly washed over sieves of finer wire-cloth until cleansed from all impurities. The grosser parts—fibre—are washed over coarse sieves. The finer parts, having precipitated, are taken up in buckets, and are fit for use; the coarse portion remains in a vat covered with water until required for use, or the dextrin may be dried by any convenient means, and preserved in the dry state. The usual proportion of dextrin to soap is from three hundred to three hundred and fifty pounds of the first, mixed with a hundred and fifty pounds of water, to every ton of tallow or oil saponified. The mixture of water and dextrin having been allowed to stand for an hour,

should be further treated with six hundred pounds of water, as subsequently described. The white soap should be made of tallow, and by steam heat; and when as much alkali has been added as can be taken up in the usual way, and when the soap is in a fit state to transfer to the frames, there is to be added from four hundred and fifty to five hundred pounds of dextrin in its wet state; and after being further mixed with six hundred pounds of boiling water, or as much as is sufficient to convert it into a thick paste, this paste is to be poured in by pailfuls into the soap, the latter being well agitated during and after each addition. When the mixture is homogeneous, and has been heated, it may be put into a frame for cooling, and afterwards cut up in the usual way. Before adding the mixture of dextrin and water, the spent lie must be pumped or otherwise withdrawn from the caldron. When, as in the ordinary method of manufacture, yellow soap is made from resin, and is *fitted* or purified from portions of imperfect soap, coloring matters, *et cetera*, it should be heated with steam, and dosed with the proper proportion of dextrin, as above directed. If no resin is used, a larger quantity of dextrin may be applied, and the operation of fitting is not then absolutely necessary. In the manufacture of either the brown or yellow variety of common soap, the addition of a quantity of the fibre, first mixed with a sufficient quantity of water to make it of thick creamy consistence, will render the product, especially when an excess of alkali is present, of much better quality and color, and it will then also dissolve much less rapidly in hot water. If a naked fire is used for the soap thus mixed, the dextrin is liable to become carbonized, and the separated charcoal would then communicate to the soap a black, or at least a darker color, than when steam is applied. The latter should therefore be always used in the above process of admixture.

A person named HAWES some years ago invented a process for the production of soap, in which intimate combination and admixture of the soap ingredients without boiling induces combination and perfect saponification of the fat with the alkali. By this method, the high degree of heat requisite in making soap by the usual process is entirely dispensed with. His mode of procedure is, as follows, described as for tallow; but, according to the inventor, it is equally applicable to the oils and fatty matters ordinarily employed as soap ingredients:—Two tons and a half of tallow, or any given quantity, are taken and melted at as low a degree of heat as possible, and then mixed with the quantity of alkaline lie required to completely saturate the tallow and convert it into soap. The mixing is performed by mechanical means. Ordinary soap boilers' lie is used, preference being given to that made from the strongest and purest alkali. The saponification of the tallow or other fatty matter, may be ascertained by its absorption or combination with the lie, care having been taken, in the first instance, to use a sufficient quantity of the latter; the proper proportion, it must be observed, varying according to the nature of the fat or oil. To each hundred pounds of tallow are required about

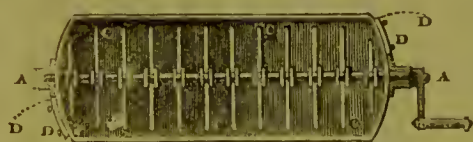
twenty gallons of lie, made from strong alkali, and of specific gravity $1.125 = 25^{\circ}$ Twaddell. An ordinary boiling caldron may be used as the combining vessel, with the addition of a machine to produce an intimate admixture, and the minute redivision of the tallow.

Fig. 507.



Figs. 507 and 508 will convey an idea of this apparatus. An upright shaft, A, Fig. 507, which may be of wood or iron, and from which arms, a, a, a, a, radiate to the sides of the caldron, is fixed permanently or temporarily in the copper. The mode of fixing and the material used, will depend on the nature of the caldron and the convenience of the manufacturer. An oscillating or rotatory motion is

Fig. 508.



given to the shaft and connected arms by any of the ordinary methods of communicating motive power. If more convenient, a cylinder—Fig. 508—may be employed, with a shaft, C, passing through it horizontally, and from which arms, c, c, c, c, c, c, radiate, when a rotatory motion will thoroughly incorporate the fatty matter and the lie. For two and a half tons of tallow the cylinder should be about six feet in diameter and twelve feet in length. At D it must be provided with convenient doors for filling and discharging the materials. The caldron or cylinder having been charged with tallow, motion is communicated to the machine, and the lie is then gradually added. In a short time every particle of the fatty matter will be brought into contact with alkaline lie, and by such means saponification will be effected. The agitation must be continued for about three hours, or until the tallow appears to be completely saponified, which is known by the mass becoming thick, after which it is allowed to stand from one to four days, according to the quantity of the paste. When a cylinder is used in the above operation, the lie is run in, and motion communicated to the shaft immediately after the introduction of the tallow, the latter being only sufficiently heated to retain it in the fluid state, and the agitation is continued from three to four hours, or less if the tallow is perfectly saponified before its expiration. As the benefit of this process arises mainly from the saponification of the ordinary materials in a comparatively cold state, it is desirable that as soon as the mass thickens and the lie is absorbed, the cylinder should be emptied and the contents turned into an ordinary caldron, preparatory to being finished and converted into yellow soap by the addition of resin, or into mottled or white soap by the operation of finishing lies, according to the usual method. By this transfer from the cylinder to the caldron, time is allowed for the combination of the tallow and alkali to become perfect.

Another method for the manufacture of soap, according to the patentee more particularly applicable to palm-oil soap, was devised by Mr. WALTERSON of Manchester. The inventor claims for his process that a purer and more perfect soap is produced in a much shorter period of time than by the ordinary method, the soap being sufficiently hard for sale or use in the course of a few hours. His method consists in a mode of mixing or combining the oils or fatty matters employed with caustic soda, and in subsequently adding water for the purpose of converting such mixture or produce into soap. The ingredients used are animal or vegetable oil, either separately or mixed, caustic soda lie of 22° Twaddell, and water if possible free from any earthy or metallic impurity. The following description of the process applies more particularly to the production of palm-oil soap, and requires to be variously modified when other oils or fats are to be saponified. The quantity of bleached palm oil taken for one operation is seven hundred and eighty-four pounds; and after having melted this in a caldron, there is to be added gradually four hundred and seven pounds of caustic soda lie, testing 22° Twaddell, and the whole is carefully and thoroughly intermixed by agitation. The heat is then gradually increased, and the mixture constantly stirred, so as not to allow it to concrete on the bottom of the pan. After the operation has been continued three or four hours, the mixture assumes a whitish appearance, and by continuing the heat the aqueous portion is entirely evaporated, and the mass reduced to a perfectly dry state. The heat is now increased, and in a short time the mass again assumes the liquid form, and becomes of a brown color, which, according to the inventor, shows that combination with the alkali has been effected. The fire is then speedily withdrawn, and the agitation of the mass is continued as long as any fear of scorching is apprehended, after which the pan is left to become cool. The solid product of this operation is then to be broken up into powder, to which is afterwards added forty-five gallons of water, and the mixture is well agitated for about half an hour. Heat is then applied, and the contents of the pan raised to boiling, and kept so for about three hours, the stirring and agitation being continued during the whole period. As soon as the evaporation has been carried to the desired extent, and the soap appears of proper consistence, it is allowed slowly to cool. The contents of the pan, still in a liquid form, are then transferred to the ordinary frames, and left to cool and solidify, and in twenty-four hours the soap will be sufficiently hard to cut into bars. Soap prepared according to the above method, is never of so fine a color as that prepared by the old process from the same ingredients; besides which it is also less pure, as it contains of course all the saline impurities of the lie. The only advantage appears to be that the soap is finished in a much shorter period, but this, in the Editor's opinion, does not counterbalance the great disadvantages above mentioned.

Since the remission of the duty on soap, a process for its manufacture has been introduced by H. C. JENNINGS, but has not been adopted on a very considerable scale; for though it undoubtedly gives a purer

and more perfect soap, the expense of production is much greater. In this method the oleaginous ingredient used is stearic or margaric acid as nearly pure as possible, and the alkali is derived from bicarbonates of potassa or soda; the fatty acids, possessing a decomposing power over these salts, render their previous caustization unnecessary. The fatty acids and solution of alkaline bicarbonate of specific gravity 1.500 are mixed in proper proportions, and heated at 212° until an intimate combination is obtained. The mass is then allowed to cool down to about 60° , and there is now added to each hundred pounds one pound of solution of ammonia of specific gravity .880, and the same quantity of the strongest caustic potassa lie. These are to be added gradually, and well stirred with the soap until thoroughly mixed. The quantity of caustic alkali required to be added is greater or less in proportion to the state of purity of the fatty acids saponified. Lastly, the separation of the soap is effected in the usual manner by means of common salt or sulphate of soda. In the manufacture of yellow soap by the preceding method, there is added previously to the addition of caustic soda or potassa lie, fifteen to eighteen pounds per cent. of resin, first dissolved by boiling with a solution of pearl ash and common soda ash in equal proportions, so as to give a solution of specific gravity 1.800, while boiling hot. This is added to the solution of soap, and afterwards there is poured in a sufficient quantity of caustic lie to produce perfect saponification, and the soap is then separated as before. The Editor would especially recommend the above process of saponification for the production of the potassa soap ordered by the London Pharmacopœia. It is indeed the only method by which a perfectly pure potassa soap can be procured. This soap not being separable from its solutions, like soda soap, by salts of soda or potassa, as ordinarily prepared, is always contaminated by glycerin and other impurities.

In the manufacture of the variety known as GWYN and WILSON'S soap, the oils and fatty matters employed are heated with concentrated sulphuric acid, by which decomposition of the fats is effected, and glycerin eliminated, while the oily acids probably enter into combination with sulphuric acid. The fat so treated becomes much harder and less readily fusible, and is likewise rendered much more easily saponifiable, although it is true that not only a greater proportion of alkali is required, but the amount of product obtained is less than when the fat is saponified in the usual way. The following is the method of procedure as described by the inventors:—Ten tons of palm oil, whale oil, or other oily matter, are put into a wrought-iron vessel provided with a perforated steam worm, through which steam is admitted until the contents are heated to 350° . The fatty matter is then run into a tank formed of brick, lined with lead, and sunk into the ground. The tank is furnished with a pipe for the introduction of steam, but which does not terminate in a worm, as it would be liable to become choked by the sediment from the fat. The cover of the tank is made of wood, lined with sheet lead, and has two man-holes closed by an oil joint about eight inches deep;

through the cover a pipe passes connected with a high shaft, to allow the escape of offensive vapors. Two thousand pounds of concentrated sulphuric acid, specific gravity 1.80, are poured into the tank, the temperature of the mass being at the same time carefully watched by means of a thermometer immersed in it, and not allowed to exceed 350° . The heat is regulated partly by slackening the speed at which the acid is poured in, and partly by diminishing the quantity of steam admitted into the tank. The introduction of steam is continued throughout the operation; but as soon as the whole of the acid has been added, the fire employed for heating the steam is extinguished, and after that the steam continued for about four hours. The steam is heated after it leaves the boiler, by passing through pipes placed over a fire. At the expiration of four hours the steam is shut off, and a large pump introduced through a pipe in the cover of the tank; then as soon as vapors cease to be evolved, and the pump can be worked, the product is pumped into a wooden vessel, lined with lead, and provided with a steam worm. In this vessel the fatty matter is washed by means of free steam, with about half its bulk of water, for two hours, and then allowed twelve hours to separate.

TOILET SOAPS — SCENTED SOAPS. — The great variety of soaps thus designated, are usually prepared by remelting and clarifying white or curd soap, and adding various perfumes, colors, *et cetera*. These operations belong more properly to perfumery than to the soap manufacture; and their preparation has therefore been included in the article devoted to the consideration of this art, Vol. II., pages 676 to 679. Sometimes, however, since the remission of the soap duty in this country, the perfumer prepares soap directly by the cold process above described, and this is a more convenient method. The marbling of these soaps is produced by rubbing up the coloring material, such as vermilion, smalts, or ultramarine, with a little olive oil or soap, a small portion of which being taken on a palette knife, is pushed through the melted mass; thus the pink color of rose soap is produced by vermilion; blue by means of ultramarine; and brown by the addition of the various kinds of ochres and umbers. The cakes or tablets are formed by placing a soft mass of soap in a mould fixed in a lever press; the mould consists of a top and bottom die, fitting into a loose ring; by a sudden pressure the shapeless mass assumes the form of the ring, and is embossed on the top and bottom. Soap is ornamented with colored cameos by first forming the cake at a press, which makes a depression for the reception of the differently-colored soap, which latter is put in by hand, and the colored portion is embossed at a second press.

A very superior and beautiful marbled soap is manufactured by the Messrs. CROSFIELD of Warrington, Lancashire.

NAPLES SOAP. — This, so highly esteemed as a shaving soap, is said to be produced by saponifying mutton suet with lime, and then separating the fatty acids from the soap so formed by means of a mineral acid. These fatty acids are afterwards combined with caustic potassa by ebullition in the usual way. FAISZT, who

examined Naples soap, gives the following as its composition centesimally:—

Fatty acids,	57.14
Potassa combined with fatty acids,	10.39
Sulphate of potassa, chloride of potassium, with a trace of carbonate of potassa,	4.22
Silica, <i>et cetera</i> ,	0.46
Water,	27.68
Loss,	0.11
	100.00

ADULTERATION.—In the manufacture of soap certain substances are frequently added besides the fat, alkali, and water essential to its production. These additions cannot always be considered as sophistications, inasmuch as in some cases the quality of the soap is thereby greatly improved. Thus, in Dr. NORMANDY's patented process, the addition of a small proportion of fused sulphate of soda to an otherwise very soft soap, confers upon it a hardness which prevents its melting or dissolving too rapidly in the process of washing. Though it may be said that the manufacturer is, by such addition, enabled to use an inferior oil or fat, still no deception is practised, as the soap so produced is little inferior in deterative properties to the soaps of the better kinds of fat, while it may be purchased at a much lower price. Other additions are also frequently made. In those cases, however, in which the substance added rather improves than deteriorates the quality of the soap, it cannot be considered as a fraud. It is true that soap is extensively and fraudulently adulterated in the true sense of the term. The Editor would remark, however, that in his opinion the public craving for cheap goods has urged upon the makers the necessity of preparing soap at a low price; and as the simplest mode of doing so was to incorporate saline water with the curd, when in the act of solidifying in the frames, to the extent commensurate with the reduced price, this mode has been adopted. So far as this addition is concerned, it does not involve the character of the manufacturer or dealer; but when the addition of water is covertly made by the maker, and the article sold as a better quality, as is frequently done, at once the public is defrauded. In like manner, dealers are in the habit of purchasing soaps at cheap rates—soaps which are highly adulterated—with the view of disposing of them at prices which better qualities command. Here, again, the consumer bears the weight of the villany, whilst its guilt presses upon the dealer, and the maker even does not escape with impunity. Certainly the maker, and the maker only, can protect the public from fraud in the matter of soap. By making certain qualities of soaps with definite and invariable amounts of ingredients, the public would in a short time become so well acquainted with the quality of the article, that inferior kinds which the cupidity of some makers might induce them to utter, would rapidly meet with its condemnation. If, however, the consumers will always purchase in the cheapest market, and whatever be the price asked, will, if possible, obtain the article at a still lower rate, they must expect to be imposed upon.

ANALYSIS.—Under this head the most important point to be considered is the proper amount of water in soaps. The proportion of water in mottled or mar-

bled soap, should never exceed thirty to thirty-five per cent. It is indeed impossible to introduce an excess of water into the paste of mottled soap, since the mottling being due to the presence of sulphide of iron and other ferruginous compounds, held partly in solution, and partly in a state of suspension, if the soap has a certain retentiveness the insoluble iron compounds would precipitate, leaving the soap perfectly white. The admixture of water with mottled soap is, however, practised in another way, namely, by plunging the soap taken from the frames into a solution of salt, when it may be made to absorb from eighty to eighty-five per cent. of water, and become so soft as to be kneaded easily between the fingers. Properly prepared white soap should contain from forty to forty-five per cent. of water. Frequently, however, the proportion amounts to fifty-five or sixty per cent., and cases have been known in which soaps, combined with from eighty-four to one hundred and fifty-four per cent. of water, have been sold. This is either added directly to the soap when run into the frames, or the soap is kept for some time in a solution of salt. The proportion of water is also sometimes increased by submitting the bars of soap to the action of high-pressure steam in tight chests or bins; also by boiling the soap in high-pressure copper before cleansing.

The proportion of water contained in a sample of soap, may be most readily ascertained by treating a portion in a water or oil bath, until it ceases to lose in weight. Two ounces or more of the sample to be examined should be taken and reduced to small thin shavings. Of these, after carefully mixing together, one hundred grains are taken, placed in a small porcelain or platinum crucible, and dried by exposure in a water bath for a sufficient length of time. When the water is completely disengaged, that is, when after repeated trials the weight remains constant, the operation is at an end. The difference between the first and last weighing indicates the per centage of water present. As previously mentioned, marbled soap should not contain more than thirty to thirty-five; and white or yellow forty to forty-five per cent. of water. The amount of water contained in soap may also be estimated indirectly as follows:—From five hundred to a thousand grains of the sample are taken and dissolved in water. To the solution hydrochloric acid is added in excess. Decomposition of the soap ensues, the greasy matters rise to the surface, and must be collected on a weighed filter, and when well washed and dried, carefully weighed, deducting the counterpoise of the filter. The filtrate, together with the washings, is now evaporated to dryness, and, after carefully drying, the weight of the residue is taken. This latter contains the alkali in the form of chloride, every one hundred parts of which indicate fifty-three parts of soda, or sixty-three of potassa soap, according as the soap under examination is a hard or a soda soap, or a soft or potassa soap. The amount of greasy matter or alkali thus ascertained is subtracted from that of the soap taken, and the remainder expresses the proportion of water present. Mottled soap treated as above should yield of fatty acids sixty-four parts, of soda six parts, and thirty parts of water. White soap should give of

fatty acids fifty parts, of soda four and a half parts, and of water forty-five and a half parts.

It is evident that if other substances are present than those indicated, the results obtained by the foregoing method will be to that extent inaccurate. In such cases the other method must be pursued, and if it is desired to estimate also the proportion of fatty acids and of alkali, special examinations must be made as will be explained presently. Whenever the object is solely the determination of the amount of water, the method by direct evaporation is the simplest and best. To ascertain the proportion of oil or fat in a given sample of soap, the following process is recommended by DUMAS:—

One hundred grains of the soap are taken and dissolved in four or five ounces of boiling water, and the solution is filtered. A sufficient quantity of dilute acid is added to effect neutralization, and afterwards a weighed portion of pure and dry white wax. The whole is then heated until the wax is liquefied, and has combined with or taken up the oil or fat liberated from the soap by the stronger acids. After allowing it to cool the cake of wax obtained is removed and weighed; the increase above the original weight of the wax indicates the proportion of fat, oil, or grease contained in the soap. If the fatty matter of the soap when liberated by the acid itself concretes on cooling, the addition of wax is unnecessary, as the fat may be weighed *per se*. The liquid decanted from the fat, or solidified wax, may afterwards be submitted to examination, to ascertain the nature and state of purity of the base. If this is intended, hydrochloric acid should be used for the liberation of the fat, and then the presence of potassa is immediately recognized by the production of the very characteristic yellow precipitate, on the addition of bichloride of platinum. To ascertain the nature of the fatty material, DUMAS directs the aqueous solution of the soap to be saturated with tartaric acid, the fatty acids to be collected, and their point of fusion carefully observed. It is a matter of great difficulty to determine the particular kind of fat or oil used in the production of the soap under examination; yet by the above method, it is possible at least to prove the identity of the fatty component; as, for instance, whether the soap is made from tallow or from oil, or whether it is of the same kind as the sample from which it may have been purchased. The odor evolved by the fatty acids at the moment of decomposition of the soap by a stronger acid, or that developed when the fatty matter so liberated is treated in a small porcelain dish, will often indicate the nature of the fatty substance employed in its production, or that at least which is present in the greatest proportion. According to NORMANDY, another test as to the quality of the soap is, that the fatty or oily acid should be readily and completely dissolved by hot alcohol. The estimation of the proportion of alkali contained in a sample of soap, is frequently a point of great difficulty. When only one alkali is present, the determination is most easily effected by means of a test acid, and the operation is performed exactly as directed in the estimation of the value of potassa, Vol. II., page 729. For hard or soda soaps in the absence of potassa, an acid is used of

which each alkalimetric division is equivalent to one grain of soda; and, therefore, when the amount of soap taken for the assay is one hundred grains, the number of measures of acid required to effect neutralization at once indicates the percentage amount of soda contained in the sample. Such an acid is prepared by adding to each measure of concentrated sulphuric acid of specific gravity 1.8 to 1.84 about nine measures of water, and mixing thoroughly by agitation. When the mixture has become cool, its exact strength is ascertained, as follows:—One hundred and seventy-one grains of pure and dry carbonate of soda are taken and dissolved in water, and the solution is heated. The alkalimeter shown in Fig. 422 is then filled up to the point marked 0° with the mixture of acid and water, and sufficient of the latter is then poured into the solution of carbonate of soda to effect neutralization. The exact point is determined by testing, from time to time, with slips of blue litmus paper; and when the latter is tinged of a slight red color, the addition of the acid is discontinued, and the number of measures employed is noted. If the whole of the hundred measures are required, the acid is of proper strength; but if any less number have been added, it is then necessary to add more water, so that a hundred divisions shall exactly neutralize the hundred and seventy-one grains of carbonate of soda, this quantity being equal to, and indeed containing, one hundred grains of pure soda. This dilution, it will be observed, may now be effected with the greatest ease; for if ninety measures are required, then to each ninety measures remaining must be added ten additional measures of water, and the quantity of the latter required to be added is, of course, greater or less in proportion to the quantity of dilute acid employed, so that one hundred divisions shall contain only as much real acid as was before contained in the number of measures used. The acid being prepared, one hundred grains of the soap to be examined are dissolved in hot water, and the solution is filtered. The alkalimeter having been filled with acid, the latter is then poured into the soap solution until exactly saturated. The number of measures required at once indicates the centesimal amount of soda present. For the estimation of the alkali in soft or potassa soaps, an acid is generally used of different strength to that indicated above. This acid is of such strength that one hundred measures represent one hundred grains of pure potassa. Full directions for its preparation will be found under POTASSA, Vol. II., page 730. The process of estimation is performed exactly in the same way as for hard soaps. The test acid for hard soap may also be used to determine the alkali in soft soaps, simply by allowing for the difference in the atomic weight of the two bases. In this case it is only necessary to calculate for every ten grains of alkali found, 15.16 grains of potassa.

In Germany, America, and some other countries, soda and potassa are frequently both used in the production of hard soap. The determination of the amount of alkali in such instances is much less easily performed. The most convenient process is as follows:—A hundred grains of the soap are taken and dissolved in water, as before, and the solution is exactly neutralized by means of the soda test acid. By a simple calcula-

tion one may then ascertain the quantity of dry sulphuric acid which it has been necessary to add, for in every hundred alkalimetric divisions of acid are contained one hundred and twenty-nine grains of anhydrous sulphuric acid. The proportion of dry acid added being known, the solution is filtered to remove the liberated fatty acids, and the filtrate evaporated to dryness. The residue, consisting of the mixed sulphates of the alkalis, is then heated to redness, and after cooling, weighed. The weight of acid added, and that of the mixed sulphates being known, the relative proportion of each alkali contained in the soap may then be easily calculated; for as one hundred parts of sulphuric acid give 177·5 of sulphate of soda, and the same quantity of the acid gives 217·5 of sulphate of potassa, if the weight of the dry sulphate obtained exceeds the ratio 100 : 177·5, the excess is due to the salt of potassa, from which the proportion of pure potassa may now be ascertained, since eighty-seven parts of sulphate of potassa represent forty-seven of potassa.

The amount of foreign matters—that is, substances other than fatty matters, alkali, and water present in soap—is determined by taking a weighed portion, and after having reduced it to thin shavings, treating them with boiling alcohol. A white soap should dissolve completely, and a mottled soap should not leave more than one per cent. The exact amount of the residue is determined by weighing it; its nature is ascertained by treating it with cold water, by which the soluble salts are extracted, and the proportion of these is estimated by evaporating the liquor to dryness. The residue unaffected by the cold water, is then treated with boiling water. The presence of starch or fecula is now recognized by the appearance of a more or less thick gelatinous mash. The filtered solution, upon the addition of a little iodide of potassium and nitric acid, or a bubble of chlorine, if starch be present, becomes violet blue. The insolubility of the residue in either hot or cold

water, denotes the presence of lime, clay, *et cetera*. If lime, it is readily soluble in hydrochloric acid, and upon the addition of ammonia and oxalate of ammonia to the solution, a white precipitate appears. What remains unaffected by alcohol, acid, and water, is clay, silica, pumice-stone, *et cetera*. The presence of an alkaline silicate in soap is detected by dissolving a portion in water, neutralizing by means of dilute hydrochloric acid; if the silicate is present in moderate quantity, silicic acid at once falls, and may be easily recognized. When it exists in lesser proportions the fatty acids should be removed by filtration, and the filtrate then evaporated to dryness, and the residue treated with water; if silica be present, it will remain as a white gritty powder, and may be collected, dried, ignited, and weighed.

It not unfrequently happens that a soap contains more or less uncombined or non-saponified fatty matter, and in this case, when the soap is dissolved in water, a film of oily matter is seen to float on the surface. MORITZ gives a method for determining the amount of this as follows:—The aqueous solution is decomposed by means of hydrochloric acid, when the fatty acids as well as the unaltered fatty matter collect together on the surface of the liquid. These are separated by filtration, thoroughly washed, and then treated with caustic baryta. The precipitate produced is thrown on a filter, washed with boiling water, and then acted upon by hot alcohol. By this means, the non-saponified grease dissolved is from the soap of baryta, and after separation of the alcohol by evaporation, its weight may be ascertained. When tested by litmus paper, it should not show an acid reaction. In the appended table, the great discrepancies in the value of different kinds of soap are clearly pointed out; yet it must be noticed that the portion of alkali in combination with the fatty acids was not separated in the analysis from that portion contained in a free state—for instance, as lie:—

Variety of Soap.	Fatty Acids.	Dry Potassa	Dry Soda.	Water.	Common Salt	Analyst.
Castile soap; specific gravity 1·0705,	76·5	"	9·0	14·5	"	URE.
Castile soap; specific gravity 0·9669,	75·2	"	10·5	14·3	"	"
Fine white toilet soap,	75·0	"	9·0	16·0	"	"
Ordinary white soap from Glasgow,	60·0	"	6·4	33·6	"	"
Mottled tallow soap of good quality, prepared from potassa after having been kept for several years, ...	81·25	1·77	8·55	8·43	"	HEEREN.
Brown resin soap from Glasgow,	70·0	"	6·5	23·5	"	URE.
London cocoa nut oil soap—marine soap,	22·0	"	4·5	73·5	"	"
Hard poppy oil soap,	76·0	"	7·0	17·0	"	"
French white soap,	50·2	"	4·6	45·2	"	THENARD.
Marseilles marbled soap,	64·0	"	6·0	30·0	"	D'ARCET.
Marseilles marbled soap,	60·0	"	6·0	34·0	"	"
White Marseilles soap,	68·4	"	10·24	21·36	"	BRACONNOT.
White Leipzig tallow soap,	76·3	"	8·8	14·7	"	ABENDROTH.
White Leipzig tallow soap,	50·0	"	9·4	29·8	"	"
Leipzig marbled soap,	45·0	"	9·8	38·0	"	"
Soap from hazel nut oil,	64·0	7·0	"	28·0	1·0	"
Soft soap,	44·0	9·5	"	46·5	"	THENARD.
London soft soap,	45·0	8·5	"	46·5	"	URE.
Belgian soft or green soap,	36·0	7·0	"	57·0	"	"
Scotch soft soap,	47·0	8·0	"	45·0	"	"
Good green soap,	34·0	9·0	"	57·0	"	"
Scotch soft rape oil,	51·6	10·0	"	38·33	"	"
Scotch soft olive oil soap,	48·0	10·0	"	42·0	"	"
Semi hard soap for fulling,	62·0	11·5	"	26·5	"	VERVIERS.
Ordinary soft soap, 1st sample,	44·0	9·5	"	46·5	"	CHEVREUL.
Ordinary soft soap, 2nd sample,	42·8	9·1	"	48·0	"	"
Ordinary soft soap, 3rd sample,	39·2	8·8	"	52·0	"	"

There are several other important considerations relating to the determination of the value of soaps, besides what is revealed by analysis. As KNAPP observes, the consumer should not be satisfied with a soap in which the amount of the dry fatty alkaline compound accords with the price, unless the soap fulfils another condition of equal importance. The problem to be solved by the soap boiler, is the production of an article from which no more is dissolved or washed away, when it is employed as a detergent, than is absolutely necessary for cleansing purposes. When this is not the case, much soap is uselessly wasted. This property of soap is carefully watched by the laundress; and for purposes of domestic economy, the quantity of soap employed is much more materially affected by it, than by the state of the articles to be cleansed. If the soap contain too much water, or its consistence be rendered too loose by reason of an excess of lie or salt disseminated through it, as is the case with many of the varieties of soap described, the waste from this cause will be proportionately great. On the contrary, if the soap is over dry, much laborious exertion will be required to detach a sufficient quantity for the purposes required. Curd soap is the only kind which maintains the proper mean between these two opposing characters, and this is due to the quantity of water which it contains, and its state of solidity. Soap that has become too dry, is improved by being kept in a moist place, and an opposite treatment improves soap that contains too much water. But, of course, as regards the foreign salts they contain, no alteration or improvement can take place. Curd soap is therefore the proper form in which soap should be sold; no deception need however be practised, when soap containing a large amount of water, as that from coconut oil is manufactured, provided a corresponding reduction be made in the price. The same applies to soap prepared from bones, fuller's earth, silicea, *et cetera*, which, if they cannot positively be called adulterations, are very much calculated, like the former, to promote dishonest traffic. The production of these articles will find very little encouragement when the soap boilers understand their own interests and responsibilities. These remarks, of course, do not apply to soft soaps which are used for entirely different purposes, and in a different manner.

USES OF SOAP.—Soap is applied for washing, for fulling woollen cloths, *et cetera*, and in medicine. Its application for washing is founded on two conditions, namely, on its power to remove fatty matters from textile and other materials, and to form therewith an emulsive mass soluble in soapy water; and on the readiness with which the neutral salts of fatty acids are decomposed by warm water into acid compounds and free alkali. The latter acts upon the impurities of substances, and forms with them compounds partly soluble, and partly such as will no longer adhere to textile fabrics and other bodies, whilst the separated acid salts of the fatty acids keep the surface of the material in a smooth condition.

STATISTICS.—The manufacture of soap is carried on more extensively in the United Kingdom than in any other country of the world. The number of manufac-

turers has gradually decreased since the year 1801, when there were six hundred and twenty-four. In 1811 the number was five hundred and twenty-two; in 1845, three hundred and fifty-six; and in 1850, three hundred and twenty-nine, besides sixty-eight remelters or perfumers. But, notwithstanding this decrease in the number of makers, it is almost needless to say that the quantity of soap produced was greater each year, and since the remission of the duty, has increased in still greater proportion. The quantity made in Great Britain in 1850, amounted to ninety-one thousand two hundred and fifty-five tons. Of this quantity five thousand six hundred and five tons were exported to foreign parts, and there were therefore detained for home consumption eighty-five thousand six hundred and fifty tons. Of this ten thousand two hundred and four tons were consumed by manufacturers of woollens, silks, and cotton. After deducting the quantity exported, and that used by manufacturers, it appears that seventy-five thousand four hundred and forty-six tons were employed for domestic purposes in Great Britain, a quantity equivalent to eight pounds and one ounce to each person. In 1851 the quantity manufactured in Great Britain amounted to ninety-one thousand nine hundred and fifty-three tons. Of this quantity England produced eighty-one thousand five hundred and sixty-nine tons, and Scotland nine thousand nine hundred and eighty-four tons. In 1852 the quantity manufactured was ninety thousand six hundred and sixty tons. In England the quantity is made up, of *hard soap* seventy-five thousand three hundred and seventy-eight tons; of *silicated soap*, five hundred and ninety tons; and of *soft soap*, five thousand six hundred and one tons. The nine thousand nine hundred and eighty-four tons produced in Scotland, consisted, of *hard soap* six thousand seven hundred and eighty-eight tons; *silicated soaps*, three tons, and of *soft soap*, three thousand one hundred and ninety-three tons. The quantity imported into Great Britain in the above year, was—from foreign countries, one thousand five hundred and thirty-three hundredweight three quarters of Naples soap; from Ireland fifty-two tons seven hundredweight of hard soap, and twenty-seven hundredweight ten pounds of soft soap. The quantity of soap produced in the latter country cannot be ascertained, as there having been no duty levied upon it, no returns were required. The annual revenue derived from the soap manufacture in Great Britain in the last years the duty was levied, exceeded one million pounds sterling. It was entirely remitted in 1853.

The following, the Editor understands, are among the largest and best soap factories in the three kingdoms:—The West of England Soap Company, Plymouth; Mr. JOHN WHEEN, London; Messrs. TYSON and RICHMOND and Mr. WILLIAM MOORE, Liverpool; Messrs. WILKIE and SOAMES, East Greenwich, London; Messrs. J. BARRINGTON and SONS, Dublin; Messrs. HOWE and Company, Old Brentford; Messrs. CHARLES TENNANT and Sons, Glasgow, *et cetera*.

SODIUM.—*Sodium*, English and French; *Natrium*, German and Latin.—This is one of the metals discovered by SIR HUMPHREY DAVY, through the agency of voltaic electricity. Moistened hydrate of soda was employed, and the oxygen both of the water and of soda was liberated at the positive pole, and the sodium of the oxide at the negative pole.

About the same time, 1807, were discovered also potassium, barium, strontium, and calcium, and, besides, traces of metallization were also obtained from the earths. The compounds of sodium with other substances are of great importance in the arts and manufactures; for example, it enters into the composition of common salt, of sulphate of soda, and of the carbonates of soda—substances so important as articles of commerce, owing to their daily employment in domestic economy, in the manufacture of glass, of soaps, in bleaching, and in numerous processes of manufacture little less important. Sodium itself, too, has lately become of great interest, and its preparation, it may safely be predicted, is destined shortly to occupy a position amongst the useful arts scarcely less important than the extraction of iron from its ores. As a metal, owing to the great facility with which it becomes oxidised, it is never likely to be much employed; but it is this very property of rapid oxidation which has caused it to be applied in the liberation of other metals from their combinations; and, from the extreme cheapness of carbonate of soda, and the facility with which sodium may be obtained from this salt, it would be doubtless possible to procure it on the large scale at a price little, if at all, higher than that of zinc.

PREPARATION.—The processes already described for the production of potassium are applicable also, with slight modifications, for the preparation of sodium. The apparatus required is also of exactly the same description as in the case of potassium. The substances employed are either hydrated soda and iron, or carbonate of soda and charcoal. These are placed in a malleable iron bottle—those in which mercury is imported answer admirably—and heated to whiteness in a powerful wind furnace. The gas, which after some time makes its appearance, is conducted into a receiver of iron or copper containing mineral naphtha or rock oil, and which receiver is kept cold by surrounding it with cold water, which is frequently changed. It should, of course, be provided with a vent for the escape of the incondensable gases evolved during the decomposition. The operation is much more productive than in the case of potassium, owing to the fortunate circumstance that sodium does not combine with carbonic oxide.

It appears, nevertheless, that the decomposition either of hydrate of soda by metallic iron, or of carbonate of soda by charcoal, is effected with greater difficulty than is the case with the corresponding potassa salts. It appears also, that by mixing the soda or carbonate of soda with a little potassa or carbonate of potassa, the operation is effected with greater facility, but the metal obtained is then a brittle alloy of sodium and potassium. From this, however, the whole of the potassium may readily be separated by means of slow oxidation, without any considerable loss of sodium. To

effect this, the alloy obtained is founded into plates, and placed in a large bottle; these are covered with naphtha, and the air in the bottle is occasionally removed. After a few days the whole of the potassium will have disappeared, and pure and very ductile sodium remains. The process usually employed in the preparation of sodium is that recommended by SCHOEDLER. The carbonate of soda used is obtained by the ignition of acetate of soda, free access of air being avoided. The object of this is to obtain the carbonate in a very pure state, since, if sulphate of soda be present, it becomes reduced in the process to sulphide of sodium, which acts strongly on the iron bottle. The mixture of carbonate of soda and charcoal obtained is to be mixed with a fourth of its weight of charcoal in fine powder, and with double this quantity of charcoal in a coarse state, to prevent fusion of the mass, which, should it occur, the fused contents spirt into the tube, and choke it up. This mixture, heated in the iron bottle, yields pure sodium, with very little black residue.

The proportion of sodium obtained by the author of this process was, from three pounds of the commercial acetate, about four and a half ounces of sodium; but in the laboratory at Giessen, even when it was obvious that the result was capable of considerable improvement, three pounds of acetate yielded nearly five ounces of sodium, the whole of the sodium present being about seven ounces. To remove the impurities from the globules of sodium, SCHOEDLER directs them to be pressed through strong and not very fine linen, the metal being first heated in naphtha to the boiling point.

PROPERTIES.—Sodium is of a silver white colour: its lustre is more brilliant than that of lead, but scarcely equals that of silver. At the ordinary temperature it is solid, but soft and ductile like wax. At 4° it is rather hard, at 32° very ductile, at 120° it is semifluid, and at 194° perfectly so. Though less fusible than potassium, it is more readily volatile, and hence a less intense heat is required in its preparation. When exposed to the air it quickly becomes tarnished, owing to the formation of a crust of soda; and if heated nearly to redness, it inflames, and emits brilliant scintillations. The specific gravity of sodium is 0.972 at 60°, and it is consequently lighter than water, and if thrown into this liquid exposed to the air it swims about, presenting the appearance of a silvery-fused globule, constantly decreasing in size and producing a hissing noise, owing to the escape of hydrogen gas. These phenomena continue until the whole is dissolved as soda.

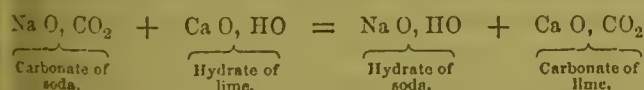
Potassium under the same circumstances takes fire, and continues to burn until dissolved; but sodium, in decomposing water, either produces less heat or requires a higher temperature to inflame it. If, however, the water be thickened with gum, so as to retard the movement of the sodium over the surface, or if there be only a few drops of water, the metal then ignites.

Sodium, like potassium, decomposes most oxides, metallic and non-metallic; also by far the greater number of salts, deoxidising not only the acid but the base also, if it happen to be oxide of a heavy metal. When thrown upon the surface of mercury, sodium

forms an amalgam, with the production of heat and light; this does not take place with potassium. Sodium is employed in the arts, principally in the preparation of aluminium, by the decomposition of the chloride of that base.

OXIDE OF SODIUM.—SODA.—When sodium is burned in dry air or in oxygen a white powder is formed, which attracts moisture and carbonic acid from the atmosphere. This is the *protoxide* of sodium— Na O . It is very similar to the protoxide of potassium, but may be known from it by the following properties:—When exposed to the air at the ordinary temperature, it first attracts moisture, becomes liquid, and, after further exposure, again solidifies; the protoxide of potassium, however, always remains moist. The other oxides of sodium are the *suboxide*— $\text{Na}_2 \text{O}$ —which is a greyish-white dull brittle mass, more combustible than the metal itself; and the *peroxide*, which is a dirty greenish-yellow substance, supposed to have the composition Na O_2 , but, never having been obtained in the pure state, this of course has not been proved. Neither of the oxides of sodium *per se* have any application in the useful arts, but the combination of the protoxide with water, namely hydrate of soda, sometimes termed simply soda, and also known as caustic soda, is an article of very great importance. It was known probably at a very early period, though, up to the time of the discovery of the alkaline metals, this and the hydrate of potassa were regarded as anhydrous alkalies.

PREPARATION.—The hydrate of soda is usually obtained by decomposition of the carbonate, by means of quick or hydrate of lime. To a boiling solution of five and a half parts of crystallized carbonate of soda, in twenty parts of water, a quantity of milk of lime, prepared by treating one and a half parts of burnt lime with four parts of warm water, is added in small portions at a time, and the mixture is boiled, with the addition of more milk of lime, until the filtered solution ceases to effervesce on the addition of an acid. The decomposition is expounded in the annexed equation—



By evaporating the solution to dryness, a hydrate of soda is obtained, which, however, usually contains traces of silicic acid, aluminic, and phosphoric acid. These impurities may be removed, except a minute trace of alumina, by treating the solid hydrate with alcohol, in which the soda salts of those acids are insoluble. In evaporating the alcoholic solution, it is necessary to add a little water from time to time to prevent blacking of the mass. Probably the purest hydrate of soda is procured by decomposing the pure sulphate by means of hydrate of baryta. The soda salt being dissolved in water, the hydrate of baryta, also in solution, is added as long as precipitation ensues. The clear solution decanted from the precipitate and carefully evaporated to dryness, yields a mass of hydrate of soda perfectly free even from alumina.

PROPERTIES.—Hydrate of soda is a white opaque brittle substance, of a fibrous texture; it fuses below

redness. In properties, it greatly resembles the corresponding salt of potassa, but is less volatile at a red heat than this salt. When exposed to the air it rapidly attracts moisture, becomes liquid, but soon dries up again; the mass becoming converted into carbonate, which, unlike the carbonate of potassa, is not deliquescent. A solution of hydrate of soda, which is very caustic and powerfully alkaline, dissolves wood, hair, the skin, and most animal matters; tallow and other unctuous substances, with formation of soaps; sulphur, and some metallic sulphides; silica, alumina, and several metallic oxides quite insoluble in water.

The following table, constructed by ZIMMERMAN, shows the quantity of soda— Na O —in alkaline menstrua at different densities:—

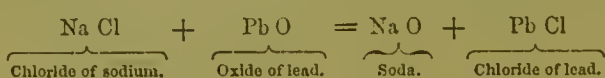
QUANTITIES OF SODA IN A SOLUTION OF SODA AT
15° CENTIGRADE—59° FAHR.—BY ZIMMERMAN.

Specific gravity.	Per cent. soda.	Specific gravity.	Per cent. soda.
1.4285	30.220	1.2392	15.110
1.4193	29.616	1.2280	14.506
1.4101	29.011	1.2176	13.901
1.4011	28.407	1.2058	13.297
1.3923	27.802	1.1948	12.692
1.3836	27.200	1.1841	12.088
1.3751	26.594	1.1734	11.484
1.3668	25.989	1.1630	10.879
1.3586	25.385	1.1528	10.275
1.3505	24.780	1.1428	9.670
1.3426	24.176	1.1330	9.066
1.3349	23.572	1.1233	8.462
1.3273	22.967	1.1137	7.857
1.3198	22.363	1.1042	7.253
1.3123	21.759	1.0948	6.648
1.3053	21.154	1.0855	6.044
1.2982	20.550	1.0764	5.440
1.2912	19.945	1.0675	4.835
1.2843	19.341	1.0587	4.231
1.2775	18.730	1.0500	3.626
1.2708	18.132	1.0414	3.022
1.2642	17.528	1.0330	2.418
1.2578	16.923	1.0246	1.813
1.2515	16.319	1.0163	1.209
1.2453	15.714	1.0081	0.604
		1.0040	0.302

Solution of caustic soda constitutes the soda lie of the soap manufacturer, and is usually prepared on the spot by decomposing carbonate of soda or *soda ash* by means of lime. The mixture is placed in large cast-iron vats and covered with water, and after some hours the lie is withdrawn through a plug at the bottom of the vat, and either fresh water or a weak lie introduced at top. Full directions for the proper performance of the process are given under the article SOAP.

The solution of soda so prepared is contaminated with the common salt, sulphate of soda, and other constituents of soda ash; these may, however, be separated in great part by concentrating the solution considerably, these salts being insoluble in a strong solution of soda. A very useful article has lately been introduced by some alkali manufacturers, intended to supersede the use of the soda ash in the soap manufacture, and in other processes of fabrication in which caustic alkali is employed; and considering the advantages likely to ensue on its introduction, and the great simplicity of the process of production, it is a matter of surprise that its preparation on the large scale has been so long delayed. The article in question is a very pure solid caustic soda, containing hydrate of soda to the amount of nearly eighty per cent.

Probably the oldest method of producing caustic soda on the large scale, though it was applied as a preliminary to the preparation of the carbonate of soda, is that originally discovered by SCHEELE. It consists in the decomposition of chloride of sodium by means of protoxide of lead or litharge. This method was employed in England by Mr. TURNER, and in France by CHAPTAL and BERARD, for producing, besides caustic soda, the fine yellow pigment designated *patent yellow*; the operation was performed by intimately mixing and rubbing together one part of salt and from four to six parts of litharge, and a little water. Double decomposition takes place between the salt and a portion of the oxide of lead, with formation of caustic soda and chloride of lead, as shown in the annexed equation:—

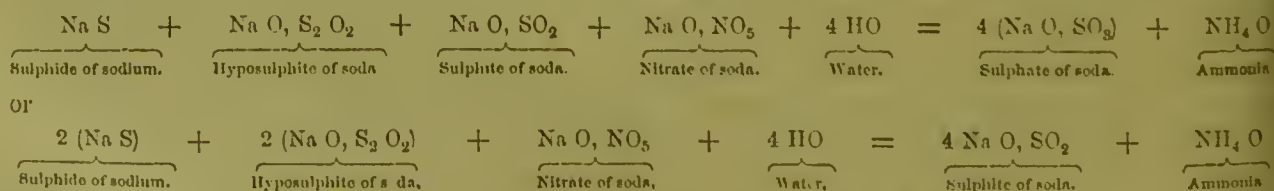


The latter salt afterwards unites with a portion of undecomposed oxide of lead, and remains as an insoluble oxychloride of lead. About twenty-four hours are required to complete the decomposition, during which time the mixture is to be constantly agitated. It is then allowed to stand a few hours to settle, and the solution of caustic soda is then decanted, the residue well washed with successive portions of water, the washings being used in the preparation of a fresh quantity. The decanted solution on evaporation yields a very pure hydrate of soda, and the lead compound, after being dried and fused, becomes of a beautiful yellow hue. The decomposition of the common salt is in this process very complete; but owing to the high price of litharge, and the limited sale of the pigment, the method has been generally abandoned as a manufacturing process.

The attention of manufacturers was first directed in 1853, by Mr. GOSSAGE, to a source of caustic soda, from which it may be obtained with great economy and by a very simple method. This source is the liquor obtained by lixiviation of black ash or ball soda, a compound which will hereafter be minutely described. The chief object of the manufacture, of which black ash is an intermediate product, is the preparation of carbonate of soda—that salt which is contained in the largest proportion in black ash liquors—and one of the principal advantages of this method of procuring caustic soda, is that by its separation from black-ash liquors, the carbonate is obtained in a considerably pure condition. The liquor resulting from the lixiviation of black ash contains carbonate of soda, sulphate of soda, and caustic or hydrate of soda, chloride

of sodium—a deep-reddish compound of sulphide of sodium—and a few other substances, in very minute quantities. When the menstruum is concentrated by boiling, crystals of monohydrated carbonate of soda separate; and if the evaporation be continued the whole of the carbonate falls in this state and can be readily separated, leaving a reddish or sometimes a blackish lie, the principal constituent of which is caustic soda. On further concentrating this mother-lie to a certain point, and adding an oxidising agent, the double sulphide of sodium and iron is decomposed, and the solution loses its deep color; any sulphates or other compounds which separate during the concentration are removed, and there remains a liquor, which in boiling to the necessary degree, affords an almost perfectly white solid hydrate of soda, contaminated with only a very small proportion of other matters. In GOSSAGE'S specification, which will be alluded to more in detail in connection with the improvements in the manufacture of *soda ash*, he directs the black-ash liquor first to be exposed to the air, so as to absorb oxygen therefrom, the effect of which is to destroy a great proportion of the double sulphide contained in such lie, and consequently, the removal of much of the coloring matter. To the menstruum so purified he gradually adds a solution of chloroxide of calcium or bleaching powder, in order to convert any hyposulphite of soda which may be present into a sulphite or sulphate of soda; he then concentrates the liquor by evaporation, and removes the whole, or nearly the whole, of the carbonate of soda and other salts, and afterwards continues the evaporation till, on cooling, a solid mass of hydrate of soda is obtained.

Prepared according to the directions given above, the caustic soda is still very highly colored, and would certainly be objected to by most consumers of this article. By a modification of the process, however, the hydrate may be obtained white, or with only the slightest possible tint; and this improved process is now generally employed by alkali manufacturers. The liquor, after the separation of the greater portion of the carbonate of soda, is conveyed to an iron boat-shaped pan, and further concentrated to remove the remainder of the salts present. Whilst the liquor is in a state of ebullition in this pan, and at a density of 1.50, nitrate of soda is added in sufficient quantity to effect the decoloration of the fluid; this salt yields oxygen to the sulphide, and converts it into sulphite, in which the sulphide of iron is insoluble; whilst its nitrogen is liberated in the form of ammonia, and the base is set free in the fluid. Thus—

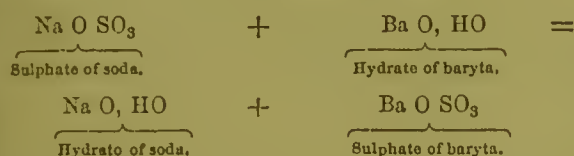


The liquor is drawn off from the forementioned pan after the salts have deposited, which happens in a period of four hours' repose, and transferred to another pan or pot, and the evaporation continued till the liquid readily solidifies on cooling. From half to one hundredweight

of the nitrate of soda is sufficient to purify such a quantity of liquor as will yield one ton of caustic soda.

A process in which caustic soda is produced was patented some years ago by Mr. WILLIAM HUNT, the principles of which were briefly as follows:—When the

product of the decomposition of sulphate of soda by coal or coke is lixiviated with water, and the solution which contains sulphide and bisulphide of sodium with caustic and carbonate of soda, is boiled with oxide of zinc or black oxide of copper, double decomposition ensues between the sulphide of sodium and the oxide of copper or zinc, and sulphide of either of the metals results, with caustic soda in the solution. The metallic sulphide thus produced is made available in the preparation of another quantity of sulphate of soda from common salt, by a process which will be described in treating of the preparation of sulphate of soda. It has been proposed also to procure caustic soda directly from the sulphate, by decomposing this salt by means of a solution of hydrate of baryta. When a solution of sulphate of soda is mixed with one of caustic baryta, changes ensue as in the annexed equation:—



Sulphate of baryta is insoluble; and, therefore, if the mixture be made in proper proportion, nothing remains in the solution but caustic soda. The difficulty of procuring with facility the requisite quantity of caustic baryta, will probably always prevent this process from becoming general. The process for the production of caustic soda on the large scale from black-ash liquors is so convenient and economical, that it will probably be never entirely superseded. If there be a demand for greater quantities than can be obtained from this source, the carbonate of soda in black-ash liquors must be converted into caustic soda by the addition of lime, and the caustic soda then separated as previously described.

Caustic soda is indeed now produced on a very large scale; and from a consideration of the advantages likely to ensue, as its use becomes more general amongst manufacturers requiring alkali, a very great increase on the present demand may certainly be expected. It is to the soap manufacturer that the introduction of this salt will prove to be the greatest stimulus the trade has received since the introduction of artificial soda; indeed, the soap manufacture will be so greatly simplified by the use of this salt, that the present mode of production may be expected in a short time to be entirely abandoned.

CHLORIDE OF SODIUM—*Common Salt, Sea Salt, Muriate of Soda; Chlorure de Sodium*, French; *Kochsalz*, German.—This substance possesses a peculiar interest, from its being one of the usual and necessary constituents of food; whilst the enormous consumption in the arts, and the variety of purposes to which it is applied in manufacturing operations, invest the study with an importance second to none. Salt is the longest known compound of sodium. As early as the time of the destruction of Sodom and Gomorrah mention is made of it in connection with the judgment against Lot's wife, *and she became a pillar of salt*. In Leviticus it is alluded to as a preservative and a component of the prescribed sacrifice. In the gospels of the New Testament its preservative qualities are

beautifully inferred from CHRIST's testimony and charge to the Apostles—*Ye are the salt of the earth, but if the salt lose its savor wherewith will it be salted*. Salt, it is said, appears in the sacred volume as the emblem of eternity, of repentance, of reconciliation, and of wisdom. NUMA among the Etruscans, and PYTHAGORAS among the Greeks, repeated the precept of MOSES—*Do not speak of Deity without fire; nor sacrifice without salt*. PYTHAGORAS calls it *a substance dear to the gods*; HOMER designates it *divine*; and PLUTARCH remarks, *it symbolizes the soul*. Salt has always been, and is now, with the Arabs, the emblem of hospitality. It figures largely in Eastern story. A thief, for instance, entering an Arab's tent at night while the master is asleep, seizes some food and becomes aware of the flavor of salt; bound involuntarily by the laws of hospitality, he withdraws, without carrying out his felonious intention. In the story of the Forty Thieves, the chief robber, who enters the house of MORIANA's master on a false pretence, is enjoined to make such excuses whenever his host offers him salt as will enable him to refuse partaking of it without suspicion.

It would be interesting if one could learn the secret of the strange yearning mankind has for salt, which ages have not diminished nor civilization annihilated. Chloride of sodium occurs in every part of the human frame. It is organized in the solids and dissolved in the fluids; it creeps into every corner of the body, and plays a part in all the complicated processes of life, without which the machinery would be arrested in its operation. In England and America, the quantity of salt consumed gives twenty pounds per annum to each person; in France the average ranges about fifteen pounds; but in some countries the love of salt amounts to a mania. In Abyssinia every man carries a lump of salt; and when he meets a friend, he offers it to him to lick. Its use may be said to be almost as universal as water, and it may safely be regarded as among the most abundant mineral compounds in nature; certainly of all the minerals eaten, none can claim so high a place in science, history, and literature, and in the kitchen it is an indispensable condiment—

Even cooks would deem't a grievous fault,
Were viands eaten without salt.

When pure, chloride of sodium consists, in one hundred parts, of 59·67 chlorine and 40·33 sodium. It crystallizes generally in the form of the cube, the crystals usually being very perfect. It may, however, under particular circumstances be made to assume other shapes, but all closely allied to the cube. When a saturated solution in water is slowly evaporated, and the surface of the fluid kept perfectly still, the crystals as they form sometimes assume a very remarkable appearance. A cubical crystal first forms on the surface; other crystals as they grow attach themselves to the edges of the upper faces; the middle cube then sinks below the surface of the liquid, but is still held up by the lateral crystals, and the process goes on until a hollow square pyramid of considerable size, having its apex downwards, may thus be produced.

Chloride of sodium is only slightly more soluble in boiling water than in cold; according to POGGIALE:—

100 parts water at 32°	dissolve	35.52 of salt.
“ “ 57.2°	“	35.87 “
“ “ 212°	“	36.61 “
“ “ 229.46°	“	40.35 “

The last is the temperature of a boiling saturated solution of common salt, which will therefore deposit very little salt on being allowed to cool; but if there be some chloride of calcium or of magnesium present, the solubility of common salt at a high temperature rapidly increases, and a considerable crop of crystals of chloride of sodium may be obtained on cooling.

Common salt decrepitates when suddenly heated, owing to a small quantity of water becoming inclosed between the plates of the crystal, and its sudden expansion at a high temperature causing a fracture of the crystal. It melts at a low red heat, and may readily be volatilized in a hot furnace. The specific gravity of pure salt is 2.557. It has an agreeable and saline taste, and is slightly deliquescent in moist air.

There are two varieties of common salt in commerce—rock-salt, and the salt produced by the purification and evaporation of salt brines. Of the latter there are in England three qualities, differing not so much in their freedom from impurities as in the size of the crystals adapting them for special purposes in the arts.

ROCK-SALT.—*Native Salt, Mineral Salt, Sal Gem.*—Rock-salt occurs as a regular mineral deposit associated with gypsum; its position is properly within the new red sandstone, but it has been met with in other situations. It occurs in layers varying in thickness from a few inches to several hundred feet. The rock is usually of a reddish-brown tint, and is rarely found colorless. The cleavage is cubical. Salt beds usually appear to have been formed by the evaporation of inland seas, the salt as it accumulated gradually filling up the bed of the sea or lake. The limited extent of these deposits, as compared with the stratified rocks over and under them, would seem to imply this. Indeed there are several instances of this kind of deposit in process of formation in various parts of the world. Thus the bed of the Dead Sea is gradually being filled up with such a deposit, and a leaden plummet dropped in deep water will bring up with it crystals of remarkable size and beauty, and at the same time almost chemically pure; but there are several lakes distributed over the globe in which the water is either quite or very nearly saturated with salt. In Asia and Africa there exist basins of sand, from which salt water has evidently been removed by evaporation, leaving the bed of the basin covered to some depth with salt; indeed, in the neighborhood of the Red Sea, and Salt Lake in Western America, every considerable depression of the soil is more or less incrusting with salt. The mines of rock-salt, most probably originating in the manner described, are not found at any determinate elevation. Thus, the great deposit extending from Upper Austria through Salzburg, is found at an elevation exceeding three thousand feet above the level of the sea; the saline rock of Arbonne in Savoy is seven thousand two hundred feet above sea level; and the immense accumulation in the Saletres of Peru, where the

salt is associated with nitrate of soda, three thousand feet; while that in Wieliczka in Poland is eight hundred and sixty feet below sea level. All these beds, like other mineral deposits, are intersected by faults, and broken up by the upheaving and subsiding of the earth; but from their limited extent, the continuity of the bed is frequently observed to be affected.

The great deposit of rock-salt that furnishes most of the salt used in England exists in Cheshire. The valley extending from near Malpas to Congleton, sweeping in the form of a crescent between the red-sandstone hills of Shropshire and the Staffordshire coal field on the one side, and the high ground of the Peckforton hills and Delamere range on the other, appears to be occupied by the saliferous and gypsiferous beds, lying as it were in a trough, to which the adjoining portions of both the above ranges dip. There are several faults and dislocations in this field; thus, at Lawton, rock-salt is found two hundred and ninety feet above sea level, while at Winsford it occurs ninety feet below, and at Frodsham Bridge no salt was found at four hundred and fifty feet below sea level. The continuity of the bed is frequently broken in the course given; and perhaps the number and depth of borings might to some appear insufficient to establish the extent of the bed; but the existence of the rock where it has not actually been reached, is ascertained with equal certainty by the peculiar sinking of the overlying ground, due to the withdrawal of the brine. The gypsiferous and saliferous beds at Northwich and Middlewich, where alone one has satisfactory information respecting them, may be estimated to be on an average seven hundred feet thick. The rock-salt lies in two beds principally. The depth to the first bed at Northwich varies with the undulations of the land, and also slightly with the irregularity of the bed itself, from ninety-six to one hundred and fifty-nine feet. At Winsford the depth is one hundred and eighty-nine feet. The thickness of the upper bed varies at Northwich from eighty-four to ninety feet in the pits sunk to the north-west, decreasing near the east border to eighty-one feet. It thins off towards the south-west, losing fifteen feet in thickness in the course of a mile. Below this lies a bed of indurated clay, thirty feet in thickness, and containing several thin veins of salt, and this overlies the second or great bed. At a pit at Marston, to the North of Northwich, this has been ascertained to be ninety-six feet thick. At Winsford, however, it is two hundred and twenty-five feet thick. At Northwich, the first sixty to seventy-five feet of rock are impure, the salt being contaminated with much clay and bituminous matter; in the next twelve or fifteen feet the salt is much clearer, and this portion only is worked. The clear portion corresponding to this is worked at Winsford at a depth of two hundred and ten feet in the rock.

The mining operations concerned in the getting of rock-salt hardly require any description. A shaft like that of a coal pit is sunk to such a depth as the position of the rock necessitates, and galleries are worked out from this. The rock is broken down by blasting, beginning at the top of the working and proceeding downwards. But little skill is required in supporting the roof from sinking in upon the miners, the rock being

so hard and firm that the galleries are worked from sixty to eighty feet broad without danger. As the rock gives off no gases injurious to animal life in any quantity, the usual great difficulty of ventilating the mines becomes easy; and sometimes the motion communicated to the air by the descent and ascent of the bucket in which the salt is wound up from the pit, is all the ventilation supplied for some months in the year.

Salt is, however, seldom found in mining operations of sufficient purity to be used in the arts, without being previously submitted to some process of purification. A pure and colorless salt is met with sometimes at Cardona in Catalonia, and in the mines of Wieliczka; and this is, therefore, simply cut into a convenient shape for the market. But most of the rock-salt mined is of a reddish hue, and contains a very small proportion of marl, a little bitumen, and a red coloring matter, analogous in character to the red fungous growth that appears on crystals of salt produced by the slow evaporation of sea-water. In addition to these impurities, rock-salt contains small quantities of various other salts, which impart to it a bitter taste, and make it deliquescent; among these are sulphate of soda and sulphate of magnesia, chloride of magnesium and chloride of calcium. But although rock-salt contains these impurities, it is a curious fact that the more deliquescent of these *are not contained in the rock as solid bodies*, but as saturated solutions in water inclosed in very minute cavities of the crystal.

Rock-salt from various mines is frequently observed to contain, pent up within its substance, a quantity of gas in a state of great compression. This phenomenon has been noticed in the rock from Wieliczka to a remarkable extent. In dissolving this salt in water a crepitation is heard, and this is occasioned by the sudden fracture of the walls of the crystal, when the gradual process of solution has reduced them so far that they are no longer capable of resisting the pressure of the inclosed gas. The gas evolved has been examined by M. DUMAS, and found to be nearly pure hydrogen. This gas may sometimes be heard blowing out in a mine like the light carbide of hydrogen of the coal mines; the quantity, however, is small, and it does not appear that an explosion has ever ensued from the incautious use of a candle.

It was customary to purify rock-salt in England formerly; but at present, salt brines of great purity and strength, and in unlimited quantity, may be obtained at so little cost, that recourse is now seldom had to the solution and subsequent evaporation of the rock. There is, therefore, little use for it, and most of the rock mined is exported. The quantity carried on the river Weaver, according to R. HUNT's report, from the 5th April, 1857, to 5th April, 1858, amounted to sixty-five thousand seven hundred and seventy-three tons.

There exists a large field of salt in Worcestershire, of which the principal bed lies three hundred feet below the surface of the ground; but the rock itself is not worked, and owing to a deficiency of borings, the geological characters of the deposit have not been so thoroughly studied as is the case with the Cheshire field. The whole of the salt prepared in the county is made by the evaporation of strong brines.

There is no country so favored in respect to the abundance and ease with which common salt may be procured as is England; and as this substance is a necessary of life, it sometimes happens that it becomes requisite in countries not so favored, to carry on the manufacture by the evaporation of very weak brines, and even of sea-water.

The following analysis may be considered to be the mean composition of the water of the ocean:—

ANALYSIS OF SEA-WATER.	
Water,	96.470
Chloride of sodium,	2.700
Chloride of potassium,	0.070
Chloride of magnesium,	0.360
Sulphate of magnesia,	0.230
Sulphate of lime,	0.140
Carbonate of lime,	0.003
Bromide of magnesium,	0.002
Iodides, <i>et cetera</i> ,	0.025
	100.000

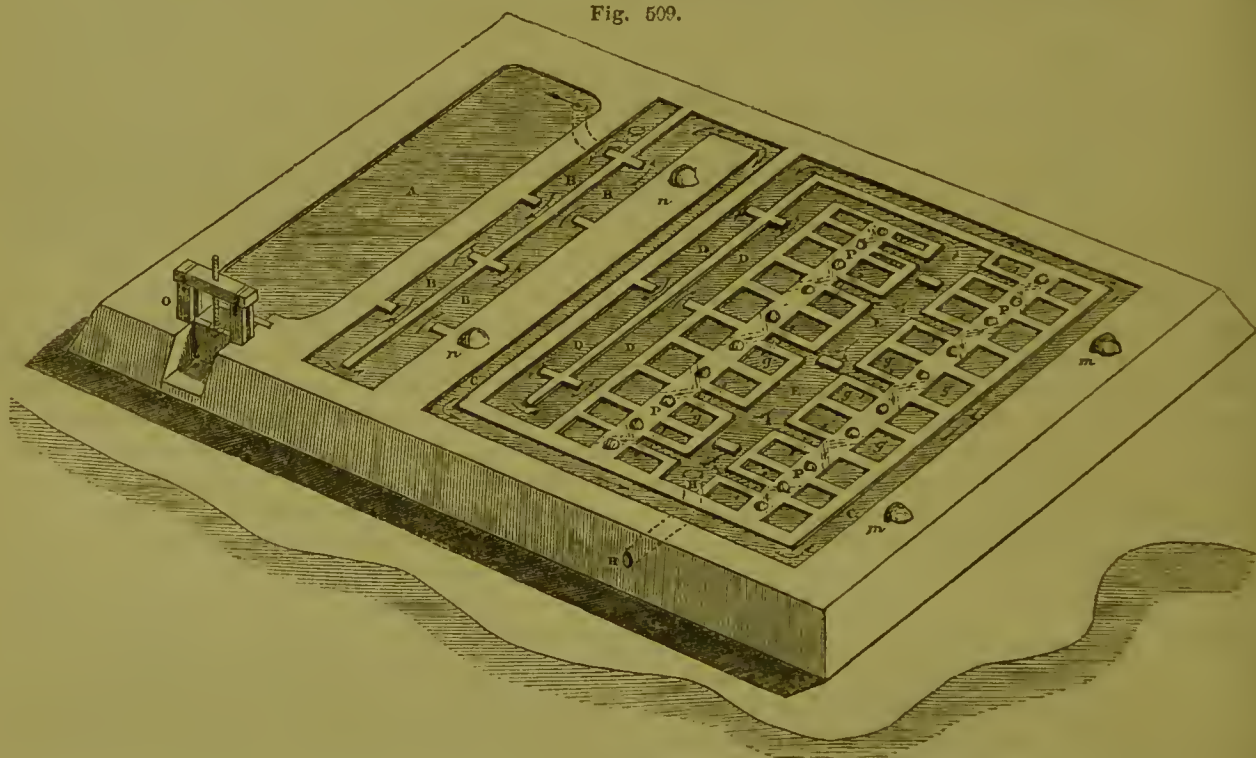
OBTAINING SALT FROM SEA-WATER.—In consequence of the small proportion of salt existing in sea-water, direct evaporation by means of fuel is never had recourse to in the preparation of common salt from this source. Slight variations are observed in the results obtained by various chemists as to the actual amount of salt in sea-water; but these discrepancies are most probably due to the influence of local causes and climate. The actual amount in the water of the Mediterranean is 2.7 per cent., as near as possible. Sea-water is always brought to a certain degree of concentration by placing it under such circumstances that it shall be most favorably affected by the drying influence of the atmosphere; and, as will be readily understood, the actual method of proceeding will vary greatly in accordance with the character, the climate, and the actual position of the works. Thus, in the South, where evaporation is rapid and the condition of the soil favorable, the sea, at the rising of the tide, is allowed to run through sluice-gates into a pond covering about an acre or more of ground, and about six feet deep. When full the gates are closed, and the water gradually deposits all the mud and matters in suspension. From this reservoir the clear water is conducted by pipes into a series of shallow basins, the whole covering some acres of ground, where, by exposing a very large surface of water to the drying influence of the sun and air, it rapidly evaporates. These basins are so arranged that the water shall flow slowly from the first reservoir downwards through the whole series, and the flow so regulated, that by the time the water arrives towards the last basins, it shall be in such a state of concentration as to deposit crystals of salt. A certain redness appearing on the surface, due to a fungous growth, is a good indication of the degree of concentration of the liquors, and its appearance is accompanied by the crystallization of the salt. The crystals as they fall are raked out at certain intervals and collected in small heaps on the ledges separating the basins one from the other. As soon as the mother-liquors begin to deposit salts of magnesia and sulphate of soda, they are run away into the sea, or they are allowed to flow into another series of evaporating ponds, to be there treated in such a way as to separate the sulphate of soda and other

salts contained in sea-water from the common salt still remaining in them.

The manufacturing process will be best seen by a reference to the woodcut—Fig. 509. A is the large reservoir into which the sea is allowed to flow at high tide through the gate, O. From this it flows through a pipe into the long canal, B B C. The flow of water is very slow, and is regulated by means of the supply pipes. The sea-water then enters the reservoirs, D D, in which the water assumes a green tint, due to the growth of conferva; these die, however, when the brine attains a specific gravity above 1.040. From the reservoirs, D D, the brine flows through the channel, E E, into the divisions, where it deposits a considerable quantity of sulphate of lime; this takes place when the brine is of a specific gravity between 1.116 and 1.145, and when it attains a specific gravity of 1.210 it no longer contains a trace of sulphate of lime—this salt being insoluble in a solution containing much sulphate of magnesia. The brine is now let into the

compartments, *gg*, where it begins to deposit common salt. The depth of liquid on these beds is not much above two or three inches, and is renewed every two or three days, according to the state of the weather. The brine is allowed to concentrate until it attains a density of 1.263, when, although the whole of the common salt has not been removed from it, the liquors are allowed to run out on the crystallizing *tables* as they are called. The salt as it deposits forms a hard incrustation on these tables, which, during the five or six months the operation is conducted, attains a thickness of about three inches. The mother-liquors are now run off the tables, and the salt scraped up and collected into small heaps, *p p*, to drain. These are collected together into larger heaps, *m, n*, and covered with straw in the form of a haystack to protect them from the rain. They are then allowed to remain for some time, that the moisture of the atmosphere may gradually remove the more deliquescent salts, consisting of the chlorides of magnesium and calcium.

Fig. 509.



The product obtained in the manner described is contaminated with clay from the bottom of the ponds, and it therefore requires to be purified by dissolving it in water, separating the clay by subsidence, and evaporating the solution to dryness. The manufacture of common salt on the plan described is carried on only during the summer months, that is, from March to September. The value of the process, of course, altogether depends upon the state of the atmosphere, and it frequently happens that a continued moist condition of this altogether arrests the evaporation.

The manufacture of salt, as described, is extensively carried on in France and Spain, and all parts bordering on the Mediterranean, and was formerly practised in England, particularly at Lymington in Hants.

In Russia, salt is manufactured by allowing sea-water to freeze, and removing the ice as it forms. The success of this process depends upon the fact, that when

sea-water partially freezes, the ice formed contains proportionately less salt than the remaining water; the mother-liquor, therefore, by repeating this process of congelation, becomes more and more impregnated with salt, until, indeed, a saturated solution of brine may in this way be formed.

Dr. WALKER, from experiments made in the Polar Seas, found that at 28.5° sea-water begins to freeze, and as the process of congelation went on he observed a saline *efflorescence* to form on the surface of the ice; but when the ice had attained a considerable thickness this efflorescence was not observed to increase, and Dr. WALKER concludes that the excess of the salt was then precipitated. It may be remarked that, according to Dr. KANE, if the cold be sufficiently intense, the water produced by melting the ice will be so far free from salt as to be fit to drink. In Dr. WALKER's experiments, however, the purest specimen of water obtained

by melting the ice formed at 42° was of specific gravity 1·005, and afforded abundant evidence of the presence of common salt, and in quantity sufficient to make the water unfit for most domestic purposes. The

salt obtained by the evaporation of the mother-liquors, as described, is however very impure, containing many of the foreign salts present in sea-water, as will be seen from the analysis as under:—

ANALYSIS OF SPECIMENS OF RUSSIAN SALT PRODUCED BY THE FREEZING PROCESS.

	Salt from			
	The Sea of Okhotsk.	Salt works at Ouskout.	Salt works at Irkoustk.	Salt works at Solouginsk.
Chloride of sodium,	77·60	74·84	91·49	74·71
Chloride of aluminium,	6·20	1·17	2·60	6·50
Chloride of calcium,	0·94	5·21	1·10	1·44
Chloride of magnesium,	1·66	3·57	2·05	3·55
Sulphate of soda,	13·60	15·20	2·76	13·80
	100·00	100·00	100·00	100·00

The salt obtained would have been of much better quality if such a quantity of milk of lime had been added to the concentrated mother-liquors as would have been sufficient to carry down the sulphuric acid, and to decompose the chlorides of calcium and of aluminium.

SALT SPRINGS AND WELLS—Brines.—When a fresh-water spring in its underground course passes

over a bed of rock-salt, it becomes more or less impregnated with that substance, and there results a salt spring or well. The amount of saline matter in salt springs, varies so much in character and quantity, as will be seen in the analyses given below, as to require a very decided difference in the method of treating them:—

ANALYSES OF SALT BRINES.

The numbers refer to one hundred parts by weight of water.

	Moutiers.	Schonebeck.	Friedrichshall.	Clemenshall.	Hall.	Sulz.	Durrenburg.	Rodenberg.	Artern.	Nauheim.	Kreuznach.	Salzhau-sen.
Chloride of sodium,....	1·058	9·623	25·5625	25·9021	25·7180	23·4733	6·599	5·173	2·829	2·3600	1·415	0·943
“ potassium, ..	..	0·007	..	..	..	..	0·008	..	0·004	0·0524	0·006	0·009
“ magnesium, ..	0·030	0·083	0·0059	..	..	..	0·092	0·166	0·038	0·0339	0·023	0·080
“ calcium,....	..	..	..	..	..	..	..	..	..	0·1935	0·261	..
Sulphate of potassa,....	..	0·014	..	..	..	..	0·004	..	0·004	..	..	..
“ lime,	0·251	0·339	0·4374	0·4445	0·1705	0·5080	0·250	0·515	0·158	0·0052	..	0·080
“ soda,	0·100	0·249	..	0·0197	0·0289	..	0·208	..	0·092	..	..	..
“ magnesia, ..	0·055	0·012	0·0221	..	..	..	0·004	0·005	0·004	..	..	..
Carbonate of lime,....	0·076	0·026	0·0100	0·0195	0·0037	0·0162	0·026	0·010	0·042	0·2133	0·003	0·057
“ magnesia,....	..	..	..	..	..	..	..	..	..	..	0·001	..
“ protox. iron.	0·012	0·001	..	..	..	..	0·004	..	0·012	..	0·005	0·001
Silicic acid, .....	..	..	..	..	..	..	..	..	..	0·0021	0·013	0·001
Organic matter,	0·001	..	..	..	..	..	0·012	..	0·017	..	..	..
Total,	1·593	10·354	26·0379	26·3859	25·9211	23·9975	7·207	5·869	3·190	2·8604	1·727	1·171

Salt wells are made artificially by pumping water into an excavated salt mine. The saturation of the water with salt is effected; and yet the process of pumping in pure water and drawing out strong brine made continuous by letting down a pipe into the well, opening nearly but not quite at the bottom. The water in the pipe was always much below the level of the great bulk of water in the well, because the sole opening in the pipe being near the bottom, it only allows that to ascend in it which has become dense from the quantity of salt it has taken up; and thus, while pure water or weak brine is pumped into the well, only strong brine is pumped out of it through the pipe.

When the brines are very weak, they are always made to undergo a preliminary evaporation in the air; and when the presence of sulphates and the chlorides of calcium and magnesium are calculated by their quantity to impair the commercial character of the product, certain purifying processes are had recourse to by which these are removed. When carbonate of iron is present in the weak brine, it is generally got rid of by exposing the brine for some time to the air. The carbonic acid by which the iron is held in solution gradually escapes

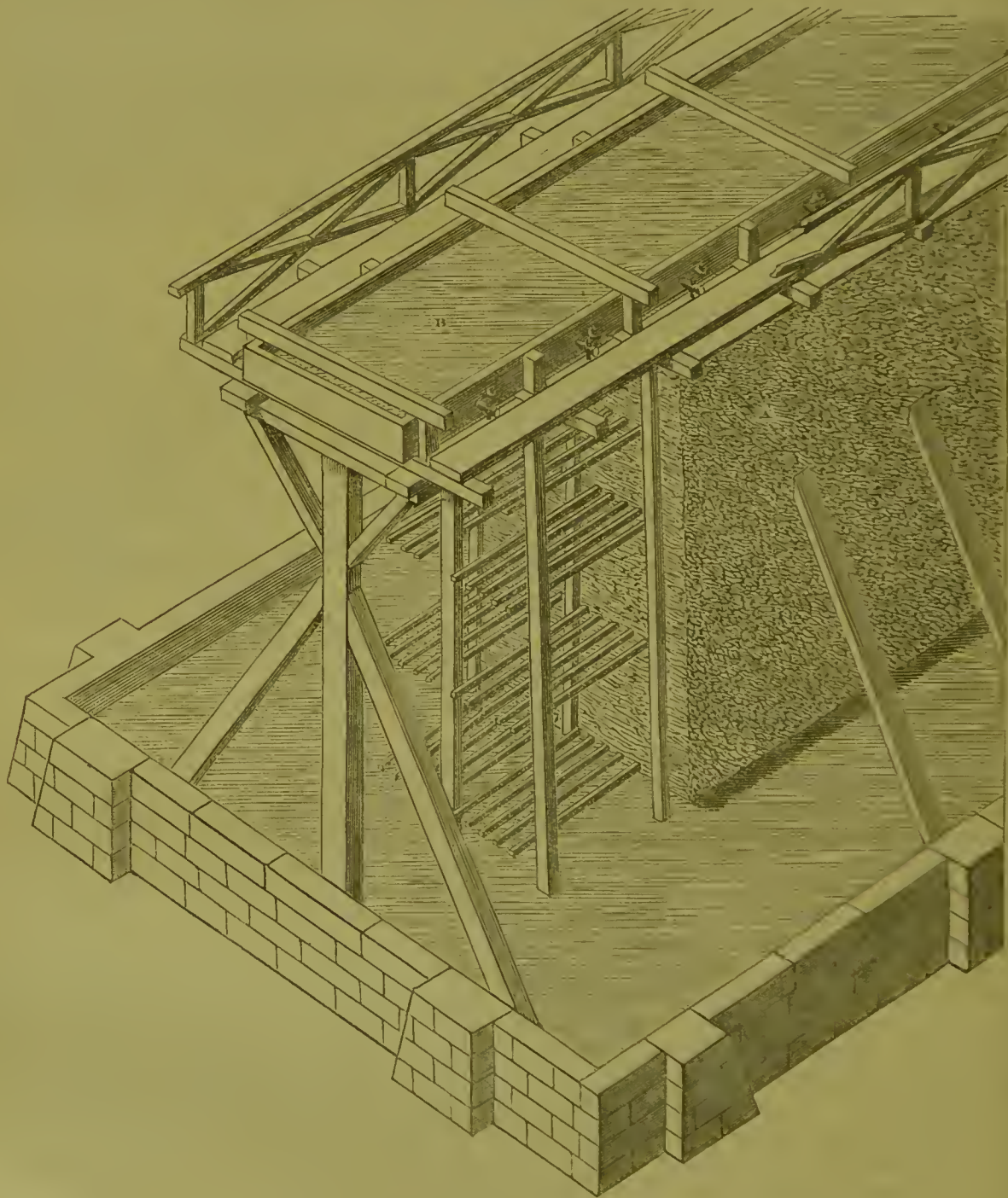
into the atmosphere, and the carbonate of iron becomes converted into sesquioxide of iron, and falls. The muddy sediment, consisting of this and a little carbonate of lime, which also falls as the carbonic acid escapes, induces the growth of certain species of confervæ, and these impart an odor of decomposing organic matter to the water, which is, however, gradually removed in the subsequent operations. The process of evaporation with weak brines is carried on in France and Germany in what are termed graduating houses. These are large wooden structures from eight hundred to upwards of five thousand feet long by about forty feet broad, covered over at the top, and open at the sides to allow a free circulation of air through the interior. The roof covers and protects from the rain several very large but shallow wooden cisterns intended to receive the brine, or there may be only one cistern, divided by wooden partitions into several separate compartments, but the extent of these divisions, their collection under one roof, or their separation, are determined by circumstances purely local, such as the character of the water, or indeed the motive power available in distributing it. The several compartments are used to contain the brine

in different stages of concentration. The first is intended to receive the brine itself; the second to receive the same after it has been concentrated by exposure to the air in minute streams, *et cetera*. The position of these graduating houses is such, that they shall be exposed in the direction of their greatest length to the prevailing winds.

Various arrangements have been devised to increase the evaporating surface of the brine; but that which now supersedes all others consists in pumping the liquor up to the summit of a high reservoir, and allow-

ing it to trickle through the interstices of a wall of thorn built up in the form of a wall and supported by woodwork. This plan was first practised in Lombardy, thence introduced into Saxony, and in 1559 these stacks were used at Bavières; and the great advantage of the plan, over the thin inclined planes and long casks then employed on the continent, began to be fully appreciated and generally adopted. The particular apparatus used will be best described from the woodcut. In Fig. 510, A is the wall of thorns, usually from thirty to fifty feet high, and from one thousand two hundred to one

Fig. 510.



thousand five hundred feet long. It is supported by wood beams firmly secured at the base with masonry. The thickness of the wall is nine feet at the base, diminishing to six feet at the summit; B, is a large

cistern intended to receive the weak brine, and furnished with a number of small taps, c c, on either side, by which the brine may be distributed over either surface of the wall.

Weak brine is pumped up into the cistern, C, and the taps are opened on that side on which the wind prevails. The brine now slowly trickles through the thorn sticks, and from the large surface it thus exposes to the drying influence of the atmosphere the brine becomes rapidly concentrated. The brine, however, is never sufficiently strong by passing through only one stack; it is therefore pumped up again and allowed to trickle through another, and so on until the liquor has attained a particular degree of saturation, which is generally something between 22° and 32° Twaddell, depending upon the price or abundance of fuel in the locality. It is then ready to be evaporated by artificial heat.

On the thorn sticks there gradually deposits a scale, consisting of oxide of iron, carbonate of lime and magnesia, and sulphate of lime, and forming what is called *thornstone*. This incrustation at length attains such a thickness as to fill up the interstices between the sticks. The stack has then to be taken down, and the thorns renewed. This happens about every five or eight years, according to the character of the brine.

The rapidity with which water is evaporated by the use of thorn stacks is remarkable. Thus at Schönebeck the thorn surface is three hundred and ninety thousand square feet, and under very favorable circumstances evaporates 3·7 cubic feet during the twenty-four hours from each square foot. And from very careful experiments by BERTHIER, at his works at Moutiers, it appears that thirteen gallons of water are evaporated under ordinary circumstances every twenty-four hours from each square foot of thorn wall. It is a remarkable fact that the water evaporated from the thorn surface is practically proportional to the surface exposed, whatever be the density of the brine. Thus, from a series of researches made at Moutiers by the above eminent chemist, brine of specific gravity 1·010 was evaporated to 1·140, and tested at three different periods to ascertain the loss; and this, as the process of concentration advanced, is expressed by the numbers 10, 12, 11. Now, the excessive evaporation indicated during the last stage was undoubtedly due to the fact of the salt itself becoming volatilized; for the experiments of BERTHIER were conducted on a large scale, and independently of the quantity carried away bodily by the wind, one recognizes, by the sense of taste, a small quantity in the air, even when the process of evaporation is very gentle and regular. The same fact is shown in a manner more decisive in the thin incrustation of salt which may be seen on glass exposed in the vicinity of salt works; and the loss of salt from this source may be estimated at about ten per cent. The results, however, of BERTHIER's experiments show that practically the rate of evaporation between a strong and a weak brine is inappreciable; although, when the experiment is conducted with great care, so as to protect the surface of the liquid from rapid currents of air, Dr. B. G. BABINGTON has shown that the degree of concentration exerts a very decided influence in respect to the amount evaporated.

When the brine in the tanks under the thorn stacks has been brought to a specific gravity of between 1·14 and 1·16, it is run out into large settling reservoirs

with just sufficient lime to decompose the chloride of magnesium. These reservoirs are of immense capacity, for the evaporation in the air taking place only during the summer months, the reservoirs are made large enough to hold a great quantity of the concentrated liquor to be evaporated during the winter months. The eight reservoirs at Salza have a capacity of nearly three million cubic feet. In these reservoirs the brine deposits all suspended matters, and the clear liquor is then run into wrought-iron tanks to be evaporated to dryness. The process of evaporating the brine to the point of saturation is termed the *schlottage* of the salt. The further evaporation to obtain dry salt is termed the *soccage*.

SCHLOTTAGE.—The pans used in this operation are from about sixty to eighty feet long, by from twenty to forty feet broad, and two feet deep, and are made of thin sheets of wrought-iron rivetted together. Each pan is heated by two or even four fires, and the flues are so built that the heat shall be distributed over the whole bottom of the pan in a manner as effective as the brick supports for the pan will allow.

The pans being three parts filled with brine, and a little blood or grease added, are brought as rapidly as possible to the boiling point. A scum now forms on the surface, which is skimmed off. This scum consists of the organic matter in the brine, and a little bitumen, which is found in all brines from natural springs. In the meanwhile the brine, which is saturated with sulphate of lime, gradually deposits this on the bottom of the pan. When about one-fourth of the original brine has been evaporated, new brine of specific gravity 1·16 is again pumped in, and the process of boiling and removing the scum is continued until the brine in the pan has been brought almost to the point of saturation; it is then run into other pans of a similar shape, and about equal capacity, to be evaporated to dryness.

The deposit on the bottom of the schlotting-pan gradually attains a thickness calculated to interfere very materially with the conducting power of the iron, and so occasions much loss of heat; the pan has then to be sealed. Of course the necessity for performing this operation will vary considerably with the degree of purity of the salt. It is usual, however, to seal the pan after it has been filled up from eight to about fifteen times.

The deposit consists of sulphate of lime and sulphate of soda, inclosing mechanically a quantity of common salt.

SOCCAGE.—This operation is performed in wrought-iron pans, similar to those described before for the schlotting process. They inclose an area of about four hundred square feet. The bottom of the pan inclines a little towards the centre. Over the pan is a dome-shaped structure of wood, terminating in a kind of chimney, for the purpose of carrying away the vapor. The woodwork supporting the dome is open at the side, immediately over the pan, that there may be a free circulation of air over the surface of the brine. During the beginning of the boiling down the pans are briskly heated; towards the end, when much salt becomes deposited on the bottom, the fires are slackened, that the bottom of the pan may not be burned.

The process is continuous, the salt being taken out as it falls by means of scoops, perforated at the bottom, to allow the mother-liquor to percolate.

In the case of lime having been added in the settling pan, or at the beginning of the settling process, the mother-liquors do not become too impure to be evaporated down to dryness, even after the pan has been filled up with new brine several times. There is also an additional advantage experienced at this stage of the manufacture, from lime having been added to throw down magnesia, inasmuch as, during the process of evaporation, chloride of magnesium forms a crust on the surface of the liquid, which re-forms almost as soon as broken, thereby preventing very materially the escape of vapor. The formation of the crust, however, may be avoided equally well by the addition of a little sulphate of soda. An interchange of elements is thus occasioned; the sulphuric acid of the soda going to the magnesia to form sulphate of magnesia, and the chlorine of the magnesium passing to the soda to form chloride of sodium. The soeage pan requires emptying out about once a month or rather oftener.

Salt having been removed from the crystallizing pans by the strainers, is collected into larger heaps on a perforated floor to drain further; it is then transferred to the drying chamber. This is simply a long chamber, heated by the flues from the fires used to evaporate the brine. These flues converge into one or two main flues, which are made to pass along the bottom of this chamber. The salt is either packed up in shallow wicker baskets, or it is put into moulds, and these are piled up above the flue in the drying chamber, and there allowed to remain until the salt no longer loses much moisture, when it is fit for the market.

In England, all the salt prepared is obtained from the evaporation of strong brines by artificial heat. The brines used are saturated, or nearly saturated solutions of salt in water, containing from 23 to 26.5 per cent. of pure chloride of sodium, besides other constituents; while a saturated solution of salt in water only contains 27 per cent. of salt. Indeed, several experiments tend to show that some brine springs would seem to hold in solution more chloride than would be taken up by the same amount of water, however long it were left in contact with dry salt.

The brine springs of Cheshire do not rise to the surface of the ground. They emerge from the surface of the rock; and when the spring is tapped, will rise in the bore hole from eighty to ninety feet. In the neighborhood of Winsford and Northwich, a shaft is sunk in the ground six feet square, and about one hundred and eighty feet deep. The sides of the shaft are carefully boarded with planks, and an inner planking of six inch boards, four feet square, is then built in, and the space between the boards well puddled with clay, to keep out the fresh-water surface springs. The inner boarding is firmly built in, and made more secure by cross-stays of stout wood. An iron pipe about nine inches internal diameter is then let down into the boring. The brine will rise in this pipe about ninety feet; it has consequently to be lifted by a pump to about the same extent. A continuation of the pipe from the pump conducts the brine into a larger

reservoir lined with masonry. This reservoir, which may be about two hundred feet long by about sixty or eighty broad, and perhaps six feet deep, is not built for the purpose of allowing sedimentary matter to deposit for the brine as it is pumped up is perfectly clear and free from particles in suspension. It is of a clear green color, and the reservoirs are built to serve as a store of brine on a high level, and from which it may be drawn down to supply the evaporating pans needed.

The evaporating pans are contained in a shed which may be four hundred feet long by about eighty feet broad, and about thirty feet high, open at the ends to permit a free current of air to pass over their surface. The pans are set in a firm foundation of brickwork, which does not, however, extend up the sides. There are generally four furnaces to each pan, and the flues are built as to support the pan, radiate over the whole of the bottom. There are usually three pans in a series, under two of which furthest removed from each other are the fire-places. The flues passing under these are continued under the third, and meet in the centre at which point they unite into one, and the flue is connected with the chimney; but so as to economize as much as possible the heat of the flue, a chamber is built over it in its course to the chimney, and this is made use of as a drying stove for the squares of salt.

The Cheshire brines, which are of specific gravity 1.200, and contain about 24 per cent. of common salt, are of so pure a quality that they require no preliminary februation. The brine is, therefore, at once run into the evaporating pans, which are of sizes varying with the source of heat, and evaporated by the direct action of the fire, or by the waste heat of the steam engine used to pump up the brine.

Those pans in which the salt is evaporated by a boiling heat, are about twenty feet square and eighteen inches deep. Those where a lower temperature is used, are about forty feet long by twenty broad, and two feet deep. The pans are made of quarter-inch iron boiler-plates rivetted together. They incline somewhat towards the end furthest removed from the fires, that more salt may be deposited on that part. The inclination is from six to eight inches in the whole length.

Three kinds of salt are manufactured in Cheshire; the difference, however, consists in the size of the crystal, depending upon the rapidity with which the evaporation is conducted. Thus the finest-grained salt is made by rapid boiling; the coarsest at a temperature of about 150°; and the medium quality between these two points.

The evaporating processes are conducted as follows:—Brine is run into a pan until it is three parts full; a little glue, and sometimes a little waste grease is then thrown in to assist in the formation of a scum, and partly to prevent the crystals of salt as they fall from adhering to the bottom of the pan. The brine is then brought to the boil as rapidly as possible, and a scum which forms on the top is removed by lightly skimming the surface with a piece of board. The crystals of salt begin to separate almost as soon as the brine is brought to the seething point, and when about half the

water has been evaporated fresh brine is run in. The salt that has boiled out is removed twice in the twenty-four hours. This operation is effected by a perforated scoop, and the salt is put into wooden moulds, or tubs, about eighteen inches high and nine inches broad at the top, and diminishing to about seven inches at the bottom. These tubs are put into the salt pan to be filled, and stand on a ledge on the side about six inches from the bottom of the pan. When the tubs are filled the salt is slightly pressed down, and the tubs are removed from the ledge on to a perforated floor, so that the mother-liquor may drain away from the salt. To allow of this there are two slits in the bottom of the tub. When the salt in the tubs has drained twelve hours, the tubs are reversed, and then withdrawn from the squares of salt, which are removed to the drying chamber, where they are allowed to remain until they become dry. From a salt-pan twenty feet square two hundred tubs of salt, each containing thirty pounds of dry salt, are removed in a day. The pans are not allowed to cool, except for purposes of cleansing, the brine being repeatedly pumped in, and the process of evaporation being continuous. About once a week the salt is more thoroughly removed than usual, and the brine in the

pan allowed to run low; the pan is then sealed over the fireplace. This operation, called *dodging* or *scabbing*, is performed with a pickaxe furnished with a long handle, and having the iron flukes flattened at the ends. A man stands on the floor that runs round the pan, and by striking with the axe he loosens the incrustation, and then removes it with a rake and spade. The scab consists of a little clay and sulphate of lime, but principally of common salt which has been burnt on to the bottom of the pan. When a pan has been worked for a month, a scale will have gradually formed over the entire bottom. The whole of the salt is then removed, the fires put out, and the mother-liquors, being of little value where there is such abundance of brine, are run away. The whole underpart of the pan is then sealed with a hammer and chisel.

The brines of Worcestershire are of higher specific gravity than those of Cheshire, and contain twenty-six per cent. of salt; but the method of working does not differ in any essential particular from the description given, and, therefore, they do not require a separate notice.

The following tables, by Dr. CAMPBELL MORFIT of New York, show the constitution in one gramme of various samples of salt:—

RANK.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Commercial Brand, and Source of the Specimen.	Key, West Solar, Florida.	St. Martin's	Liverpool Rock.	Kiskiminitas from Tarentum, Pa.	Oso	Liverpool fine.	Liverpool ground alum.	Cudwell's boiled, from Syracuse, New York.	New York.
Chloride of sodium,	0.993514	0.985266	0.982713	0.977931	0.975485	0.969917	0.969423	0.968882	0.968488
Water,	0.008000	0.007000	0.005000	0.019000	0.020000	0.005000	0.014000	0.012000	0.012000
Insoluble residue,	0.000050	0.002000	0.006000	0.000200	0.000300	0.000400	0.000700	0.000400	0.001100
Chloride of potassium, ....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chloride of calcium,	0.000119	.....	.....	0.003017	.....	.....	.....	.....	0.002671
Chloride of magnesium,	0.000934	0.002123	0.002547	0.000849	0.002123	0.006708	0.005774	0.000849	0.002547
Sulphate of lime,	0.000554	0.000510	0.001700	.....	0.001900	0.010005	0.003011	0.014300	0.015624
Sulphate of potassa, .....	.....	.....	S. trace.	.....	.....	.....	S. trace.	.....	trace.
Sulphate of soda, .....	.....	0.002520	0.000659	.....	0.001364	0.004330	0.007628	0.003085	.....
Nitrate of soda,	trace.	.....	S. trace.	trace.	.....	.....	.....	.....	trace.
Silicate of soda,	trace.	0.000336	0.000505	0.000252	0.000505	.....	trace.	trace.	.....
Organic matter—soluble, ..	.....	.....	.....	.....	trace.	.....	.....	.....	.....
Iron (Fe_2O_3),	0.000800	0.000400	0.001100	0.000200	trace.	0.000500	0.000700	0.000400	0.000800
Alumina (Al_2O_3), .....	.....	0.000200	.....	0.000500	0.002000	0.000600	0.000900	0.001200	0.000500
Total,	1.003971	1.000355	1.000224	1.001949	1.003677	0.997460	0.999136	1.001116	1.003730

RANK.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Commercial Brand, and Source of the Specimen,	Kanawha, Virginia.	Haskin's salina, coarse, from Syracuse, New York.	Goose Creek, Kentucky.	Bonaler,	Spencer's boiled, from Syracuse, New York.	Hopo Factory, New York.	Nassau,	Angulla,	Syracuse Company, New York.
Chloride of sodium,	0.967460	0.965540	0.964276	0.963288	0.962938	0.962851	0.960321	0.957348	0.956663
Water,	0.022000	0.014000	0.022000	0.017000	0.022000	0.014000	0.011000	0.022000	0.016000
Insoluble residue,	0.000600	0.000000	0.000300	0.001000	0.000300	0.000600	0.001000	0.005800	0.001800
Chloride of potassium,	S. trace.	.....	S. trace.	.....	trace.	.....	.....	.....	.....
Chloride of calcium,	0.003257	.....	0.007747	.....	0.000009	.....	.....	.....	.....
Chloride of magnesium,	0.002887	0.000509	0.001613	0.007132	0.002717	0.002123	0.008665	0.002293	0.000509
Sulphate of lime, .....	.....	0.014500	.....	0.004000	0.013992	0.016500	0.004800	0.008600	0.020000
Sulphate of potassa, .....	.....	S. trace.	.....	S. trace.	.....	trace.	.....	.....	.....
Sulphate of soda, .....	.....	0.000809	.....	0.006777	trace.	0.000667	0.009562	0.004410	0.002978
Nitrate of soda,	trace.	.....	.....	.....	.....	.....	trace.	trace.	.....
Silicate of soda,	0.000421	0.000252	trace.	0.000168	0.000168	0.000168	0.000673	0.000168	0.000168
Organic matter—soluble, ..	.....	trace.	.....	.....	trace.	.....	.....	.....	.....
Iron (Fe_2O_3),	0.000400	0.000500	.....	0.000500	0.000800	0.000600	0.000500	0.000200	0.000700
Alumina (Al_2O_3),	0.000400	0.001300	.....	0.001700	0.001700	0.002000	0.000500	0.001200	0.001300
Total,	0.997325	0.998010	0.995936	1.001565	1.001624	0.999509	0.997021	1.002019	1.000118

TABLE—(Continued.)

RANK.	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Commercial Brand, and Source of the Specimen,	Tarentum, Pa.	Liverpool Ashton,	Turk's Island,	Pomeroy, Ohio,	Curaçoa,	Alleghany saline, Penna.,	Cañiz,	St. Uba,	I
Chloride of sodium,	0.943494	0.941656	0.940776	0.938382	0.929816	0.915437	0.913722	0.890402	0.878500
Water,	0.040000	0.044000	0.032000	0.046000	0.053000	0.064000	0.063000	0.061000	0.056000
Insoluble residue,	0.000300	0.000500	0.003600	trace.	0.001500	0.000800	0.001700	0.001900	0.002000
Chloride of potassium, . . . .	.....	.....	.....	S. trace.	.....	.....	.....	.....	.....
Chloride of calcium,	0.007541	.....	.....	0.008971	.....	0.013495	.....	.....	0.004844
Chloride of magnesium,	0.008491	0.002462	0.007047	0.005095	0.011036	0.005394	0.010699	0.023870	0.002041
Sulphate of lime,	0.002740	0.012200	0.009400	.....	0.002300	.....	0.003300	0.009800	0.010000
Sulphate of potassa, . . . . .	.....	trace.	trace.	.....	trace.	.....	trace.	trace.	.....
Sulphate of soda, . . . . .	.....	0.001262	9.007530	.....	0.007208	.....	0.009942	0.014475	.....
Nitrate of soda,	trace.	.....	.....	.....	.....	.....	trace.	.....	trace.
Silicate of soda,	0.000336	0.000421	.....	trace.	trace.	0.000505	0.000252	0.000337	0.000336
Organic matter—soluble, . . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....
Iron (Fe_2O_3),	0.000200	0.000200	0.001000	trace.	trace.	0.000200	0.000300	0.000400	0.000100
Alumina (Al_2O_3),	0.000600	0.000200	0.000600	trace.	trace.	0.000200	0.000700	0.000500	0.000200
Total,	1.003702	1.002901	1.001953	0.998448	1.004860	1.000031	1.003615	0.002682	0.995641

This article would be incomplete without adverting to the saline springs of Syraeuse, in the state of New York. Numbers VIII., XI., XIV., and XVIII., in the analyses by MORFIT are samples from this district. The springs of Syraeuse, to which in a great measure the growth and prosperity of New York are attributable, are among the most interesting natural productions with which America is blessed. They occupy a circuit of about nine miles around the Southern extremity of the Onondaga lake. The salt is obtained from the water by the heat of the sun. The process of obtaining salt by solar evaporation is very simple. A series of wooden vats are built, twelve feet wide, six inches deep, and several rods in length. The brine is let into the first tier direct from the reservoir, and is left in repose until the dirt and other impurities have subsided. The clear supernatant liquor is then drawn off by siphons into the second tier of vats, which are lower than the first, where the sulphate of lime is deposited in beautiful crystals. The brine, thus purified, is redrawn off into the third and lowest tier of vats, where by exposure it evaporates, and the crystallization of chloride of sodium commences. At first the crystals are seen on the surface of the brine, and resemble drops of melted tallow let fall upon a surface of cold water. These particles accumulate, and precipitate themselves to the bottom of the vat in large quadrangular and hexangular crystals of the purest salt, hard, dry, and of a beautiful white color. This Onondaga solar or coarse salt is unsurpassed, it is said, in the world, and its antiseptic properties are widely known and appreciated. The rapidity of the process, and the consequent proportional crop, depends upon the heat of the weather; the process of evaporation being greatly retarded by a humid atmosphere. Sunshine is of course desirable at the salt works, and the superintendent keeps a close watch upon the weather. At the first symptoms of a shower all hands are immediately summoned to *push on the covers*, and the temporary roof, which is passed on rollers over the crystallizing brine, is ready to be removed the very instant the sun shines again.

The state of New York, through its superintendent, bores the wells, procures the supply of brine, and conduits it through logs to the salt works, which are the property of individuals. The localities are leased at a nominal rent, and for an indefinite number of years, but are only to be employed for the manufacture of salt. For the *raw material* a tax of one cent per bushel is levied on every bushel of salt produced. This amounted in 1856 to fifty-nine thousand nine hundred and forty-six dollars and forty-four cents: the expenses were fifty thousand two hundred and fifty-five dollars and sixty-five cents.

PHYSIOLOGICAL EFFECTS.—In minute quantity chloride of sodium is injurious to very few, if any plants, and to some it appears to be beneficial. Used moderately, it is on certain lands a most excellent fertilizer.

Salt serves many important and essential uses in the animal economy. It is employed, on account of its agreeable taste, by the people of all nations. It is an invariable constituent of the healthy blood. There is a deficiency of this saline constituent in cholera.

As a chemical antidote, chloride of sodium may be administered in poisoning by nitrate of silver. As an alterative and tonic, it is useful in scrofula and glandular diseases. As an astringent in hemorrhage, dysentery, and diarrhoea, it has been given in conjunction with lime or lemon juice. It is frequently employed as a dentifrice.

As an external application, salt has been employed for various purposes. A saturated solution, applied with friction, is used as a counterirritant and disient in glandular enlargements and chronic diseases of the joints; as a stimulant, it is rubbed on the chest in fainting and asphyxia.

The inmates of every sea-side infirmary can tell a yet happy tale of the beneficence of salt breezes. They speak of lingering diseases fortunately ended; of long convalescence speedily consummated by cure. Many a life which seemed gradually ebbing away in the atmosphere of a crowded city hospital, have these briny vapors called back and fortified, and cheered

with long years of health. Salt plays here the part of a good fairy: it makes of this infirmity a kind of healing heaven for the bodily sick.

The duty on salt was repealed in 1823; but in 1815 the makers of bleaching powder were allowed to use rock salt duty free, under the inspection of the excise, who required that the salt should be crushed at the mines and mixed with a certain proportion of ground manganese, so as to render it unfit for curing purposes. The Editor's father decomposed salt which was six pounds a ton in Dublin in the year 1819. Mr. MUSPRATT mixed it with oil of vitriol, condensing the evolved hydrochloric acid in a series of stone jars. It was in Liverpool, in 1823, that he first decomposed salt in an *open* furnace, *disregarding entirely the hydrochloric acid*, which escaped and was diffused throughout the atmosphere. The salt he employed at first was termed *herring salt*, and cost forty shillings a ton. The price now is only eight shillings.

RETURN OF SALT COMPILED AND ISSUED BY THE NORTHWICH AND WINSFORD CHAMBER OF COMMERCE.

	Tons.
White salt carried on the river Weaver from 5th April, 1857, to 5th April, 1858,	647,437
Rock salt,	65,773
Carried by rail from Winsford and Northwich, estimated at	525,000

WORCESTERSHIRE.

Stoke and Droitwich,	196,500
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IRELAND.

Duncone, near Carrickfergus, belonging to the Belfast Mining Company, shipped	16,660
Used for manufacturing purposes,	5,798
White salt manufactured,	4,877

Total produce of the United Kingdom,	1,462,045
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TOTAL QUANTITY OF WHITE SALT EXPORTED FROM JANUARY 1 TO DECEMBER 31.

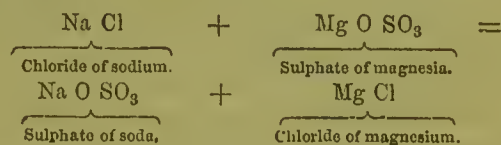
	Tons.
1855,	583,770
1856,	720,689
1857,	648,516

ROCK SALT EXPORTED.

1857,	87,119
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SULPHATE OF SODA.—GLAUBER'S SALT.—SALT CAKE.—*Sulfate de Soude*, French; *Schwefelsaures Natron*, German.—This salt was discovered by GLAUBER in 1658, and since that time has been commonly known by his name. It exists in nature in both the mineral, vegetal, and animal kingdoms. It is a very common ingredient of mineral springs of the purgative class, and is also one of the salts met with in small quantity in most terrestrial waters. Amongst the English medicinal waters, it exists in considerable quantity in those of Cheltenham, of Leamington, and of Spital.

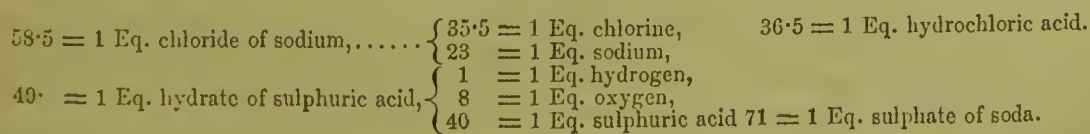
In some springs, as in that of Paipa among the Andes, it is so abundant that crystals of it are formed upon the surface over which the water is thrown; it is likewise found in crystals in the brine springs at Salinas d'Espartinas, near Madrid. In the latter locality the sulphate exists as *Thenardite*; while in the former it is in the hydrated state, or *Mirabilite*. GMELIN accounts for its presence in mineral waters, on the supposition that it is formed by double decomposition from common salt and sulphate of magnesia contained in the liquid, thus—



Sulphate of soda in the form of mirabilite is also found in several localities in Austria, in Bohemia, in the Tyrol, and in several places in Spain and Hungary, as well as in Switzerland; on lavas, and as an efflorescence on the Siberian and Caspian steppes. A mixture of the crystallized salt with gypsum—*Glauberite*—was discovered by GIMBERNAT in the canton of Argovie in Switzerland; the same compound has been found in crystals and reniform masses, embedded in rock salt, at Villarubia in Spain, at Vic in Lorraine, Berchtolsgaden in Bavaria, and at Atacama in Chili. In the vegetal kingdom, sulphate of soda is found in the ashes of some plants which grow by the sea-shore, as the *Tamarix gallica*; and lastly, it is found in some of the animal fluids, as the blood and urine. Artificially this salt is extensively made, and its production being the first stage of the process for the conversion of common salt into carbonate of soda, it is a most important article in commerce.

It is obtained by heating common salt with sulphuric acid, and is also a by-product in the preparation of nitric acid, of sal ammoniac, of carbonate of magnesia, in the amalgamation of silver ores; and it may also be obtained from many glass slags, if native or artificial soda has been used in the preparation of the glass.

Preparation.—Sulphate of soda may be most conveniently prepared in the pure state, by causing liquid sulphuric acid to react on chloride of sodium. When the two substances are mixed, violent effervescence ensues, hydrochloric acid being evolved; the effervescence having partially subsided, heat is applied to the vessel, and continued until the whole of the hydrochloric acid is expelled, and the mass becomes dry. The following diagram shows the change that takes place:—



The dry mass obtained as above, usually contains a little sulphuric acid more than is required to produce neutral sulphate of soda. This is removed, after solution in water, by the addition of a sufficient quantity of carbonate of lime, or the excess of acid may be neutralized by the addition of carbonate of soda. The

solution is now to be filtered, evaporated, and set aside to crystallize. The crystals obtained by resolution and recrystallization yield the salt chemically pure. Or the menstruum may be obtained directly by dissolving carbonate of soda in dilute sulphuric acid.

Crystallized sulphate of soda, procured as above,

contains to each equivalent of sulphate ten equivalents of water, and consequently, is represented by the formula $\text{Na O, SO}_3, 10 \text{ HO}$. The anhydrous salt is obtained by heating the crystals to redness, or, according to FARADAY, in anhydrous crystals, by evaporating an aqueous solution at a temperature considerably below 212° . MISTCHERLICH gives the degree at 104° , and others state it to be as low as 91° .

Properties.—The primitive form of the ordinary crystallized sulphate is the oblique rhombic prism. The anhydrous salt forms in crystals belonging to the right prismatic system. This latter, which is transparent, when exposed to the air becomes opaque on the surface, owing to absorption of water. The taste of the crystallized salt is cooling and bitterish saline. By exposure to the air it effloresces, with the loss of all its water. The perfectly effloresced salt intumesces in very moist air to three times its bulk, and then becomes a crystalline mass of ordinary Glauber's salt, with a slight excess of water. When the crystallized salt is heated, it undergoes the aqueous fusion, gives off its water, and thereby becomes a white solid; but at a red heat this again becomes liquid. One part of the crystals dissolves in three parts of water at 60° ; at 212° water dissolves its own weight of the salt. It is insoluble in alcohol. A crystallized sulphate of soda is also known, containing eight equivalents of water, and having the formula $\text{Na O SO}_3, 8 \text{ HO}$.

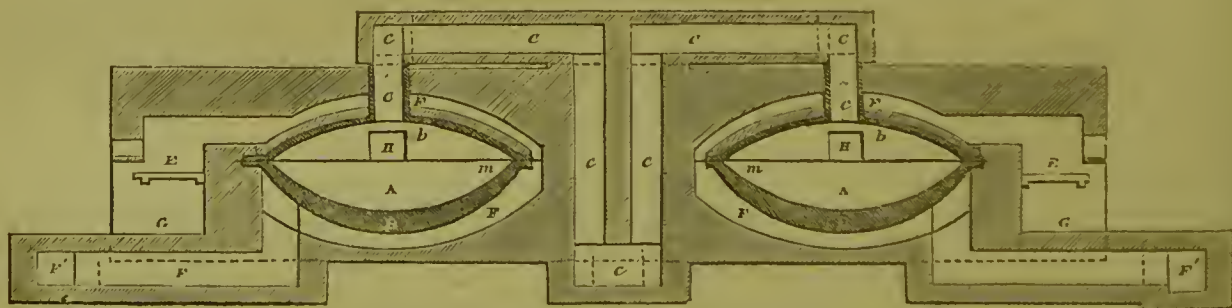
Physiological Effects.—Sulphate of soda is a mild but efficient cooling laxative or purgative salt, promoting secretion and exhalation from the mucous membrane of the stomach and bowels without causing inflammation or fever. It was formerly the most favorite saline cathartic in this and other European countries, but since the beginning of the present century has gradually been displaced by the sulphate of magnesia.

Manufacture of Sulphate of Soda.—Sulphate of soda possesses more than a chemical interest. Its preparation, as previously mentioned, is the first stage of the

process now so extensively carried on for the conversion of common salt into carbonate of soda. In the preparation of the dry salt, technically known as *salt cake*, sulphuric acid is caused to act upon common salt in a proper apparatus, the products of the reaction being salt cake and hydrochloric acid. Until of late years the decomposition was effected in an ordinary reverberating furnace, named the decomposing furnace. Some furnaces of this kind were constructed with two compartments, in one of which the materials were mixed, the greater part of the gas liberated, and the liquid evaporated to a pasty condition; in the other the calcination of the residuary sulphate was effected. In many decomposing furnaces the whole operation was carried on in the same division. An important improvement on this plan of decomposition was effected by introducing into the decomposing bed of the double furnace a lining of sheet lead, upon which the materials are mixed and brought to a pasty consistency, and they are then removed to the roasting bed to be more completely freed from acid. Furnaces of this kind are still in use in many alkali works. But for the most complete apparatus for the production of salt cake, manufacturers are indebted to Mr. JOHN LEE, who proposed the substitution of a concave iron pan for the leaden one previously employed. The advantages obtained by the use of these pans are, first, a great diminution of the expense of production, since the leaden pans rapidly become corroded during the process; and, secondly, that with the iron pan a much stronger sulphuric acid may be employed to effect the decomposition, with the further advantage of preventing the formation of so much bisulphate of soda as by the old method.

A description of the annexed woodcuts—Figs. 511 to 514—will show the most approved form of apparatus in use at the present day. Fig. 511 is a transverse section of two decomposing pans, A, A, formed of cast-iron, weighing about five tons each, and suitably set in brickwork, so as to allow the bottom and sides to be

Fig. 511.



exposed to the fire. The pans are covered with a sheet of iron, *b*, the joints made good with luting. *E* is the fireplace; and the flues, *F, F*, pass over and under the pans, but not through them. The roof of the pan is not always constructed of iron; a brick roof is frequently in use, the arch being higher in proportion to allow of its being self-supporting.

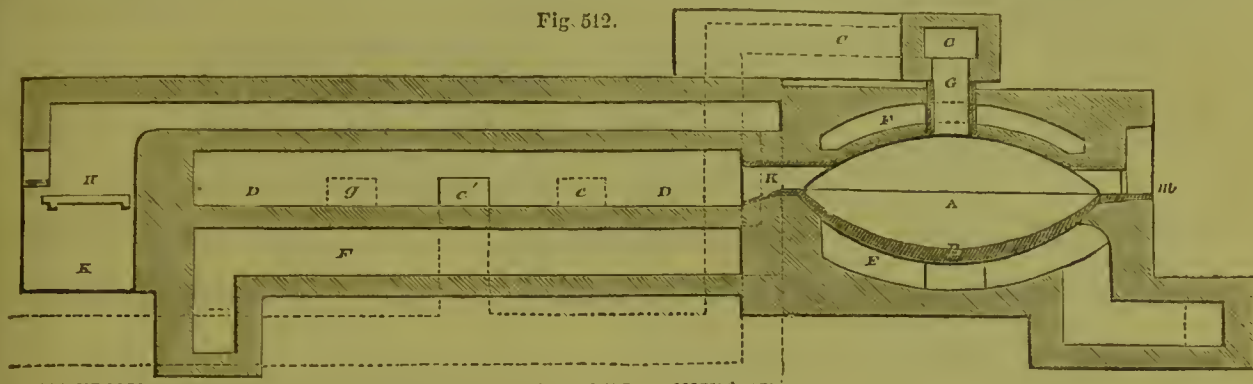
There are three openings into each of the pans, one through which the charge is introduced, and shown at *h*; the other immediately opposite, through which the charge is pushed out, seen at *k*, in Fig. 512; the

third is for the escape of the acid vapors through the pipe, *c c*. This pipe is composed of short lengths of closed earthenware fitting into one another, and well luted to prevent escape of gas.

Two of these pans are usually worked together, and the hydrochloric acid gas brought into one main flue, as shown in the figure. The salt cake furnace is attached to the decomposing pan, as shown in Fig. 512. The sole of this furnace, which is flat, is constructed of good fire-brick or Welsh tiles, and the roof, which is only slightly arched, is of fire-brick. *h* is the fireplace,

and *F F* are the flues passing over and under the furnace, but not through it. *G* and *E* are openings for the purpose of turning over and withdrawing the charge. *C* is the tube through which the acid gas escapes.

Fig. 512.



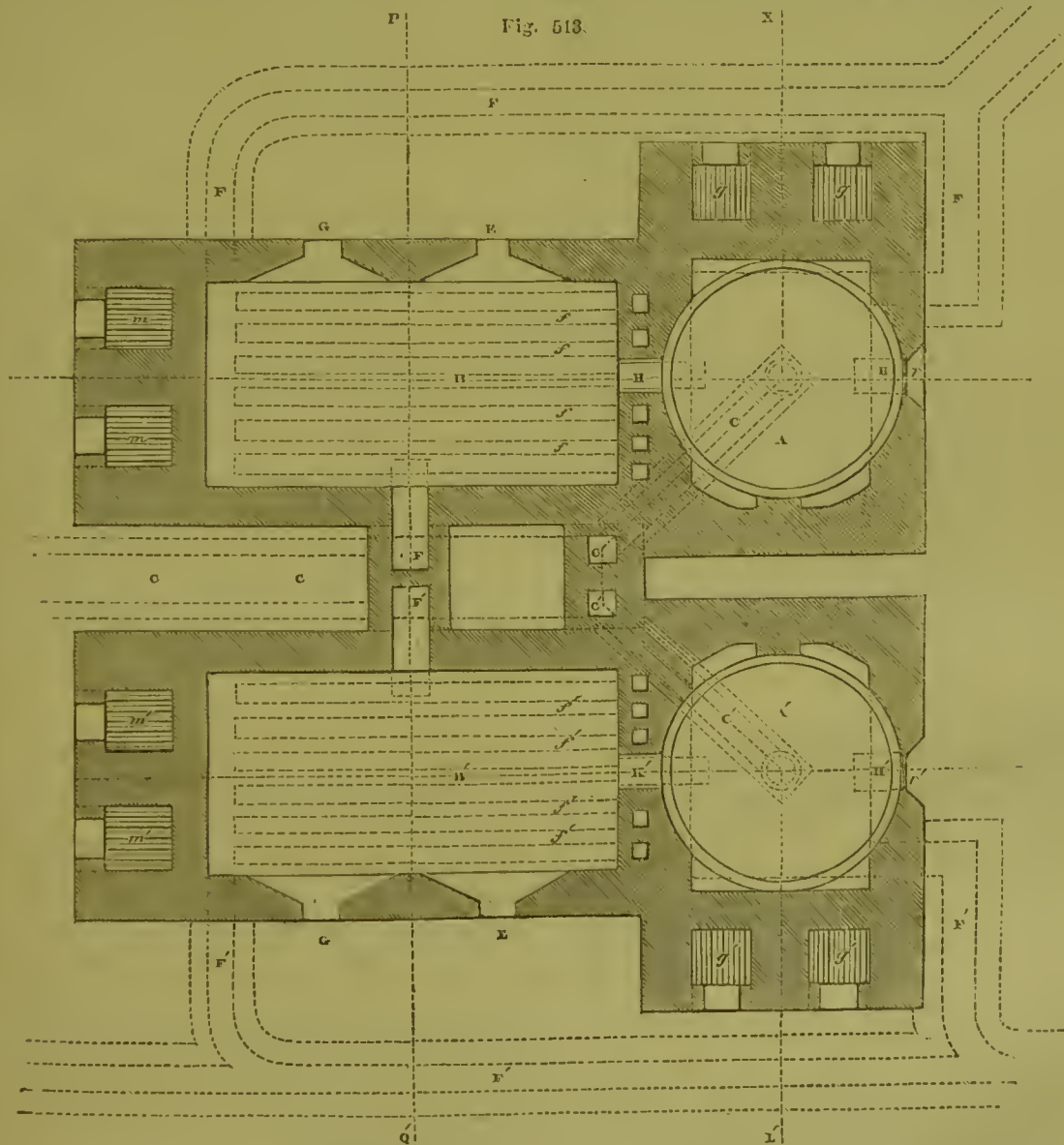
The charge is pushed into the furnace from the decomposing pan through *K*.

Fig. 513 shows a plan of the decomposing pans and furnaces. *A A'* are the decomposing pans; *C C'*, the acid flues; *F F'*, and the dotted lines, *f f f*, show the arrangement of smoke flues.

Fig. 514 is a transverse section of the same through *P, F, Q*, in which the arrangement of flues is plainly seen.

The following is the method of producing salt cake with the use of the apparatus described. The pan, *A*, is first heated to a suitable temperature, and the

Fig. 513.



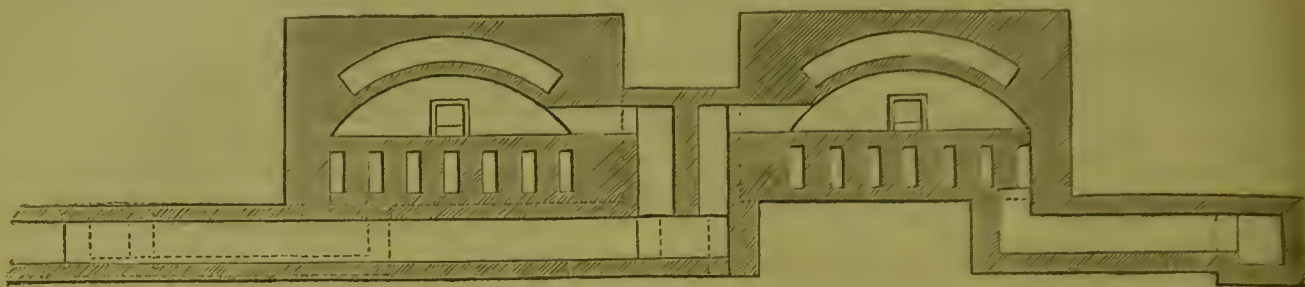
charge of salt, amounting to about sixteen hundred-weight, is introduced through the doorway, *U*. The tile which closes this is now fitted into its place, and the sul-

phuric acid is run in. It is preferred to use acid of about specific gravity, 1.450, and heated to a temperature of about 120°, so as not to cool the pan more than is neces-

sary. The proportion of acid required is about one thousand eight hundred pounds, or one hundred and

twenty-three and a half gallons, that being the quantity which, making allowance for water and slight impurities

Fig. 514.



in the salt, is just sufficient to convert all the chloride of sodium into sulphate of soda; and the charge is usually measured out by filling a small leaden vessel, of known capacity, placed near or over the decomposing pan, so as to allow of the acid being run in upon the salt by a siphon. The acid and salt having both been introduced, the tile closing the opening, *H*, is now removed, and the materials thoroughly mixed with an iron rake. This mixing serves at the same time to prevent frothing, by facilitating the escape of gas. The doorway is then effectually closed with the tile and properly luted, and the fire urged under the pan. In the course of an hour nearly all the acid vapor will have been disengaged, and the greater portion of the common salt be converted into sulphate of soda. Much of the sulphuric acid, however, is now found combined with soda as bisulphate of soda; and to decompose this, so as to render the excess of acid serviceable in forming sulphate of soda with the undecomposed common salt, a high temperature is required, to obtain which the charge is now pushed forward through the opening, *K*, into the salt cake furnace, *D D'*—Fig. 512—by means of rakes inserted through *H*. The charge is spread evenly over the floor of the furnace, the tools being worked through the doorways, *E* and *G*. The salts are here exposed to a low red heat for about one hour, and frequently turned over during this interval. Meanwhile the decomposing pan having remained empty for a time, to enable the workman to raise the temperature to the proper extent, a new charge of common salt and acid is introduced, and worked off in the manner described.

The sulphate of soda is heated in the salt cake furnace until it assumes a reddish-yellow tint, when it is raked out through the doorway, *G*, and is considered finished.

From two furnaces, such as shown in the drawings, and of the dimensions given, ten charges each may be drawn in a day, or sixteen tons of common salt may be decomposed, with the production of nearly nineteen tons of salt cake. The working of sulphate of soda is effected, however, under different arrangements, in a manner even more rapid than this. Thus, when an open reverberatory furnace is used in place of the closed furnace described, sixteen charges a day may be drawn; the open furnace being capable of more rapid heating than the *blind or closed furnace* described, and the acid gases being more readily carried away by the current of air passing over the heated salt.

Condensation of the Hydrochloric Acid.—It now remains to consider the various plans adopted to effect the condensation of the hydrochloric acid gas evolved from the mixture of acid and salt. The whole or nearly the whole of this was, in the early days of the manufacture, allowed to escape into the air, the inconvenience attending its condensation having been considered of greater consequence than the value of the liquid acid. But owing to the great demand for bleaching powder, the manufacturer found it would be to his interest to condense the *whole* of the acid, so as to use it in the preparation of bleaching agents.

The plan of apparatus at present employed for effecting the condensation of gaseous hydrochloric acid to the liquid form, was first suggested and patented in 1836 by Mr. GOSSAGE; the condensers have, however, been greatly improved since that period. The gas, as evolved from the mixture of sulphuric acid and salt, is conducted by means of pipes inserted in the brickwork of the dome of the pot, and in the arch of the furnace, to a massive tower or series of towers—Fig. 515—constructed of large rectangular slabs of silicious stone, cemented together and bound exteriorly by stout iron clamps. These towers may be filled with small pebbles or rounded flints, but usually coke is preferred, and a stream of water is allowed to flow from a cistern on the top slowly through the mass; this, meeting with the ascending gas, completely condenses it, and ultimately flows out by an aperture in the bottom to a recipient. The mode of condensing adopted previously to the introduction of these towers was, as previously stated, by a series of WOLFE's bottles; a system far too cumbersome to be adapted successfully on the very extensive scale on which the manufacture is now carried on.

A connection exists between the first and second towers near the summit, and from the base of the second tower an underground flue, for the purpose of creating a draught through the apparatus, is carried to the chimney-stalk. The gases eliminated from the mixture of salt and sulphuric acid enter the first tower at its base, and pass upwards through the moistened coke; whatever is uncondensed is carried into the second tower, and in its passage through this downwards the whole of the acid is removed; and the uncondensable gases pass by the flue to the chimney.

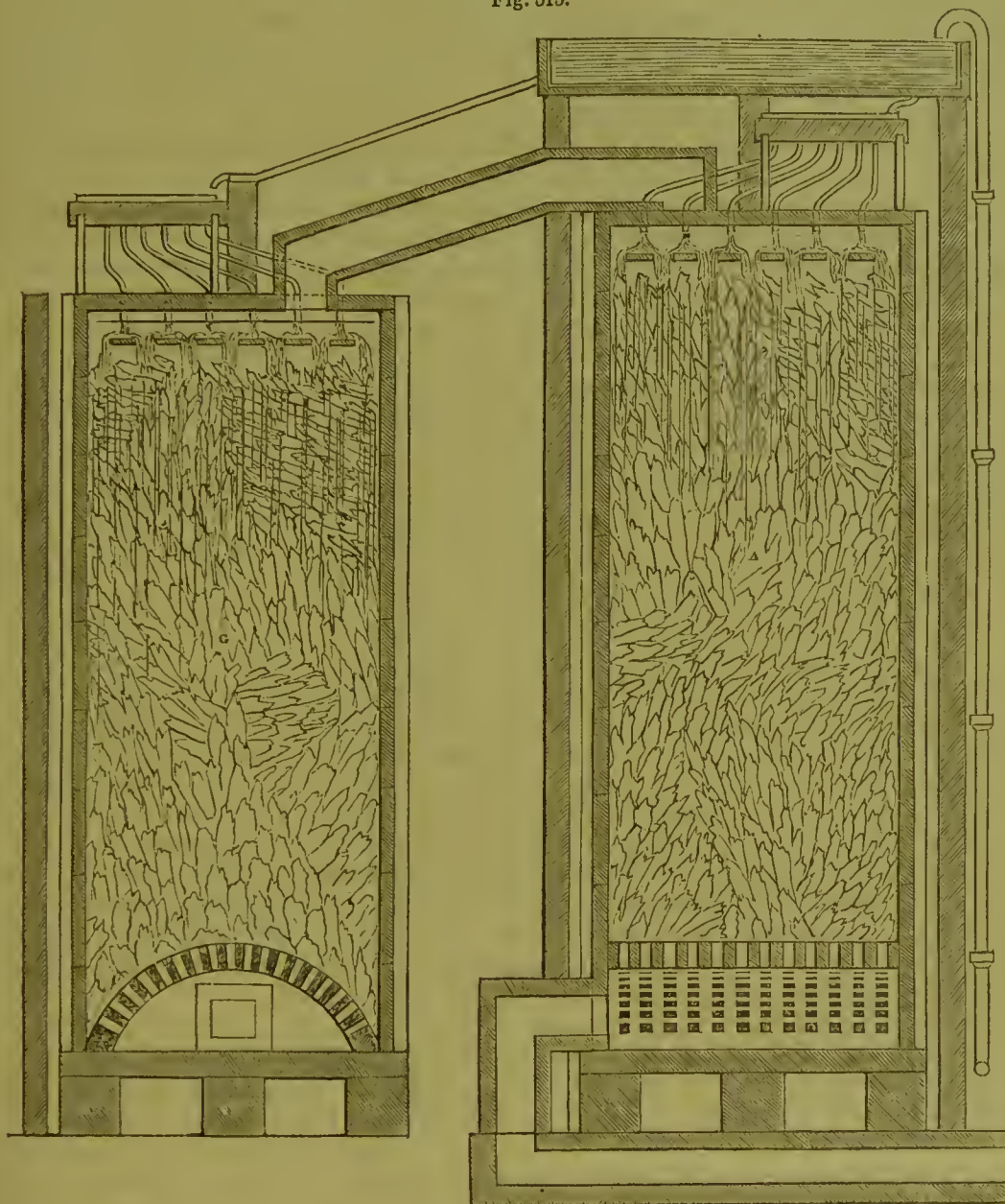
If the towers are of sufficient height, two only will be requisite to effect complete condensation of the acid; but if this should not be the case, three or more may be connected together; the first two at the summit,

the second and third at the base; the third with the fourth at the top, and so on through the series. By this arrangement acid may be obtained of specific

gravity 1.150 to 1.160, quite strong enough for the decomposition of binoxide of manganese.

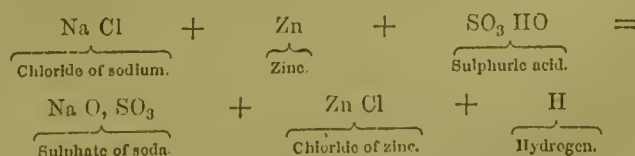
If the hydrochloric acid be required for other pur-

Fig. 515.



poses than the decomposition of binoxide of manganese, as for the evolution of carbonic acid from chalk or limestone, condensers of a still more simple nature may be employed; because then, a weaker acid answering the purpose equally well with a strong one, a far greater proportion of water may be used. In this case, a single tower divided into two compartments by a partition wall, and the whole well filled with small pieces of coke and supplied with water in sufficient quantity, will effect the condensation of the whole of the acid evolved. But unless the acid can be at once consumed on the spot, it is of course always desirable to obtain it in as concentrated a condition as possible. In some manufactories, as well to prevent the escape of hydrochloric acid as for economy, the towers, constructed as above described, are filled with limestone instead of coke or pebbles; and the carbonic acid evolved is applied in the preparation of bicarbonate

of soda, as will be hereafter mentioned. It has also been proposed to avoid the evolution of hydrochloric acid altogether, by adding sulphuric acid and zinc to a solution of chloride of sodium. In this case, hydrogen is eliminated, and there is produced chloride of zinc and sulphate of soda as in the annexed equation:—



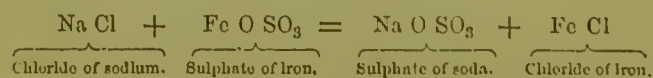
The products can be separated by crystallization; and from the mother-liquor, lime will precipitate hydrate of zinc, which can afterwards be substituted for metallic zinc, for the production of sulphate of soda from common salt.

Various other processes for the preparation of salt-

cako have been adopted on a more or less extensive scale. In some of these, hydrochloric acid is also obtained; in others chlorine, or a mixture of this and hydrochloric acid; and in others, the chlorine is removed in combination with bases. One of the oldest of these methods consists in heating together in a reverberatory furnace a mixture of common salt and pyrites—bisulphide of iron. In this process, the sulphur of the bisulphide becomes oxidised to sulphuric acid, under the influence of heat, atmospheric air, and of sodium; and the sodium being at the same time converted into soda, combines with the acid produced. The chlorine of the common salt partly combines with the iron, and the other portion unites with the hydrogen of the water or steam evolved from the combustible materials employed to form hydrochloric acid. The heat being continued, the chloride of iron at first formed becomes decomposed; nearly pure chlorine is evolved, and sesquioxide of iron remains in admixture with the sulphate of soda. By lixiviating the mass with water, the sulphate of soda is dissolved; and by evaporating the solution, the pure salt may be obtained in crystals, or as an anhydrous mass. Mr. LONGMAID, some years ago, proposed this method for the preparation of sulphate of soda for the alkali manufacturer, and at the same time of pure chlorine for the production of bleaching powder. He suggested that the chlorine might be freed from hydrochloric acid by bringing it in contact with a surface of wood, kept moist from the outside; and the gas from it, if to be used in the production of bleaching powder, must then be dried by any convenient method. The mixture of sulphate of soda and oxide of iron he directs to be employed, instead of the pure sulphate, in the preparation of black ash according to the usual process.

This plan is not likely to supersede the old method of manufacture; for, besides the great defect arising from the slowness with which the decomposition of the common salt proceeds, there is, according to DUMAS, a considerable loss of sulphur during the process, owing to the incomplete oxidation of this element. This portion of sulphur is evolved as sulphurous acid in admixture with hydrochloric acid.

Protosulphate of iron has been used to a considerable extent for the conversion of chloride of sodium into sulphate of soda. This may be effected in two ways; firstly, by dissolving the copperas and salt together in water, when a double decomposition takes place, with formation of sulphate of soda and protochloride of iron as in the annexed equation:—



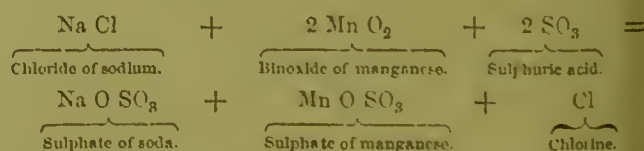
The sulphate of soda may be procured in hydrated crystals— $\text{Na O SO}_3, 10 \text{ H}_2\text{O}$ —by exposing the solution to a low temperature; or, in an anhydrous state as an opaque precipitate, by concentrating the solution at the boiling point. In either case the chloride of iron remains in the mother-liquor.

The other process for the conversion of chloride of sodium into sulphate of soda, by means of sulphate of iron, consists in the calcination at a red heat, in a reverberatory furnace, of an intimate mixture of the

two salts in the proportion of sixty parts of chloride of sodium to one hundred and forty of the iron salt. In this case, there is formed, at first, sulphate of soda and chloride of iron as above. By heat, however, the chloride is transformed, by virtue of the decomposition of water, into hydrochloric acid, which is disengaged, and into oxide of iron, which remains mixed with the sulphate of soda. There is also eliminated a little sulphuric acid and chlorine. DUMAS states that the process may be rendered more productive of sulphate of soda, by mixing the two substances together in powder, and leaving the mixture for some days in a heap moistened with water, and afterwards heating to redness. This mode of manufacture of sulphate of soda is employed in the North of France.

Among the processes for the manufacture of caustic soda, that of Mr. WILLIAM HUNT has been mentioned. It consists in the decomposition of sulphide of sodium by means of oxide of zinc or of copper, when there are produced caustic soda and sulphide of copper or zinc. The metallic sulphide thus obtained, he directs to be applied in the preparation of sulphate of soda, either by roasting so as to produce sulphuric acid in the ordinary manner, and causing this to act upon common salt; or by heating the sulphide to a temperature of about 400° , with exposure to the air, whereby the sulphide is converted into sulphate. The sulphate of copper or zinc thus obtained, after having been freed from the accompanying oxide or unaltered sulphide by lixiviation with water, is mixed with a solution of common salt, when there are produced sulphate of soda and chloride of zinc or of copper. The alkaline sulphate is separated from the metallic chloride by crystallization, and from the chloride remaining in the mother-liquor, oxides of zinc or of copper, in a condition to be used for the decomposition of more alkaline sulphide, is obtained by the addition to the solution of milk of lime.

The preparation of sulphate of soda and of chlorine for bleaching powder was carried on simultaneously at former periods. The process which was first adopted by the Messrs. TENNANT and Company of Glasgow, consists in heating together a mixture of chloride of sodium, binoxide of manganese, and sulphuric acid in leaden vessels, when changes ensue, as represented in the subjoined equation:—



The whole of the chlorine of the common salt is therefore evolved in the pure state, while there remains a mixture of sulphate of soda, sulphate of manganese, and the excess of sulphuric acid employed. To this as much common salt is added as is necessary to saturate the free sulphuric acid, and the whole is heated in a reverberatory furnace. In this operation, the manganese and iron-salts are decomposed; and the sulphate of soda may then be withdrawn from the fused mass with water. It will be observed that in this process one half of the sulphuric acid employed is lost; and this

being of greater value than the equivalent proportion of hydrochloric acid lost in the other methods of treatment, the plan has been generally abandoned.

Besides these sources of sulphate of soda, it is obtained also frequently from the mother liquors of common salt. When these solutions are sufficiently concentrated, a substance separates in flakes, which is a double salt composed of sulphate of soda and sulphate of lime. This is collected, washed with cold water to remove adhering chloride of sodium, and then treated with boiling water. The sulphate of soda now dissolves; and the solution, after being allowed to deposit, is decanted and evaporated to the crystallizing point or to dryness. The sulphate of soda in these liquors is probably formed by double decomposition of sulphate of magnesia and chloride of sodium.

Crude salt cake, prepared by the action of sulphuric acid upon common salt, usually contains from ninety-two to ninety-six per cent. of sulphate of soda, and, besides free sulphuric acid, chloride of sodium, minute quantities of other matters, as sesquioxide of iron, *et cetera*. A sample prepared at the works of JAMES MUSPRATT and Sons, Liverpool, was examined in the Editor's laboratory, and gave the following results:—

Sulphate of soda,.....	96.515
Sulphate of lime,.....	0.923
Sulphuric acid,.....	0.616
Chloride of sodium,.....	1.345
Sesquioxide of iron,.....	0.191
Water,.....	0.187
Insoluble matter, coal, <i>et cetera</i> ,.....	0.130
Loss, ...	0.093
	100.000

NITRATE OF SODA—CUBIC NITRE—SODA-SALT-PETRE.—*Nitrate de soude*, French; *Salpetersaures Natron*, German.—Nitrate of soda may be prepared artificially by saturating nitric acid with carbonate of soda, and evaporating the solution to dryness; by precipitating nitrate of baryta or of lime with sulphate of soda, allowing the solution to deposit the insoluble earthy sulphate, decanting the clear liquor, evaporating and allowing the nitrate to crystallize; and lastly by mixing solutions of nitrate of potassa and of sulphate of soda, when double decomposition succeeds, producing sulphate of potassa and nitrate of soda. The latter salt, being much the more soluble of the two, remains in the liquid after the former has crystallized, and may be obtained as already directed. The pure salt may likewise be obtained from the common variety, by dissolving the latter in the least quantity of boiling water, filtering the liquid whilst hot, and stirring the filtrate till quite cold. The crystalline deposit which forms during the last operation is transferred to a funnel loosely plugged with cotton, allowed to drain, and then washed by pouring on it cold water in small portions at a time, allowing each washing to drain off thoroughly before the succeeding edulcoration, and continuing the operation till the washings give no milkiness with nitrate of silver. The powder is then dried.

Properties.—Nitrate of soda crystallizes in transparent rhombohedral prisms; it has a cooling and bitter taste. Water dissolves it with great reduction of temperature; three parts at 60°, one part at 125°,

and much less than its own weight at 212°, are required to dissolve one part of the salt. It becomes damp only in moist air; but, according to some chemists, deliquesces perfectly in an atmosphere saturated with watery vapor. When heated, it melts and evolves at first pure oxygen gas; afterwards the oxygen becomes mixed with nitrogen, and fumes of nitrous acid. It detonates with charcoal and other combustible bodies, but less violently than the corresponding salt of potassa. It is composed centesimally of—

	At. weight.	Centesimally.
1 Eq. of soda,	31	36.47
1 Eq. of nitric acid,	54	63.53
	85	100.00

Its chemical symbol is Na O, NO_5 .

COMMERCIAL NITRATE OF SODA.—*Sources.*—This compound is not a manufactured product, but is found associated with other saline bodies distributed over various parts of the earth in the form of a mineral deposit, or as an efflorescence on the surface of the ground. Associated with nitrate of potassa, it is met with in Spain and in various parts of India; but the most remarkable deposit of this salt occurs in Peru, where a tract of country one league long and several broad, in all comprising, perhaps, fifty square leagues, is more or less incrustated with that substance. The existence of this salt in Peru has been known for about a century, and in 1820 some of it was sent to England; but the duty imposed was so high that it was not brought into the country. Between 1820 and 1830 several attempts were made to induce manufacturers to use the salt in England, America, and France; but it was not until 1831, that its real value as an article of commerce became generally known.

On the coast of Peru the land rises in a very precipitous manner to the height of about four thousand feet above sea-level; at this height the rocks shelve down a little into the country, and the view opens out on a plain of immense extent, varied only by slight undulations of the surface. These grounds, called the Pampas, are dry, arid plains, on which hardly a trace of vegetation is seen; plants of the cactus family even scarcely being able to maintain a struggling existence. No rain falls on these plains; and the deep blue of the sky or the bright glare of the sun is never obscured by a cloud; even the phenomenon of wind is hardly known; and the character of the locality is that of stillness, so profound indeed as to impress itself upon both man and beast.

From thirty to thirty-five miles from the coast, just before reaching the level ground of the Pampas, are found the deposits of nitrate of soda most esteemed for their purity and most easily procurable from their thickness. The depth of the layers varies from a few inches on the level plains to four, and even seven feet, on the slopes and hollows of the ground. The salt is found on the surface of the ground, or covered only to a very slight extent with a hard crust, consisting of a mixture of common salt and clay. This crust increases in thickness in some parts to four or five feet; and the crude nitrate or *nitrate calèche*, as

it is termed, under the thick layers, is the material most sought after for its purity. The workable nitrate—being that found of sufficient thickness—occurs in patches of about five hundred yards, mean breadth; and the character and value of the deposit varies considerably even within the limit of a few hundred yards. From an examination of several samples, the crude material has been found to contain on an average from twenty-five to thirty per cent. of impurity; this consisting principally of common salt, but associated with small quantities of chloride of iron, sulphate of soda, sulphate of lime, and iodide of sodium, and in some specimens clay.

Purification.—It has already been observed that the purest layers of nitrate lie under a hard crust of earthy matter, mixed with chloride of sodium; this is so hard that it is usual to employ the aid of gunpowder in dislodging the material by blasting. The powder used for this purpose is a coarse material made on the spot from the nitrate of soda, charcoal, and sulphur; the charge, where the vein of salt and the covering is thick, will frequently be three hundredweight, and this will dislodge upwards of twenty tons of salt. The pieces thrown up are broken with hammers, and a selection is made of the purest specimens. The crude product obtained in the manner described is, however, very seldom found in such a condition of purity as to be capable of immediate application in the arts; and the great difficulty of getting the salt from the *officinos* or *lurks* to the coast, renders it imperative to purify the substance as much as possible in the localities that yield it. The process of purification usually adopted is, however, extremely simple, and is dependent on the difference in solubility between common salt—which is the principal foreign substance—and the nitrate of soda, at temperatures above the common.

The apparatus employed for this purpose consists of two dissolving vessels, a settling pan, and several crystallizing pans. The dissolving vessels are hemispherical pans of cast-iron, about six or seven feet diameter and three or four feet deep. They are dead-set in brick-work, and one fire plays round and between them. Into these vessels a quantity of mother-liquor, saturated with common salt from a preceding operation, is run, and a charge of nitrate *calèche*, consisting of fifteen quintals, is now thrown in, and the whole boiled for four or five hours, until the liquid is considered to be saturated with nitrate of soda. The solution is now ladled by hand into a settling pan, in which the liquid clarifies by subsidence. In a few hours the clear lie, still hot, is drawn off into shallow coolers, constructed of boiler-plate iron, and in these the nitrate of soda crystallizes out as the liquor cools. The crystals are shovelled out on to the ground, and dried by exposure to the sun, while the mother-liquor is made available for the solution of a further quantity of the crude material. The ordinary yield of crystals from fifteen quintals of nitrate *calèche*, is from eight to ten quintals, or about seven and a half hundredweight. A quantity of these dry crystals, sufficient for a load, is now introduced into two bags; these are slung on the back of a mule, and with this load the animal winds down the sides of the mountain to the sea-coast. The

mother-liquors, after being used for several operations, become charged to a considerable extent with iodide of sodium, when that substance is a constituent of the crude material, but little iodine is obtained from this source, although, with proper management and utensils, the working might be made a profitable investment. The use of steam has been tried in purifying the crude nitrate, but with only partial success. The apparatus employed for this purpose consists in an iron vessel constructed in the form of an inverted cone, both ends being open. This vessel is filled with nitrate *calèche* and steam blown in through the bottom of the cone. The great solubility of the nitrate of soda in water, and its powerful attraction for that substance, induces the separation from the common salt, and a saturated solution of nitrate of soda, made by the condensed steam, flows out through the bottom of the cone. But owing to the necessity for introducing the crude material in lumps, a great portion of the soluble part in the interior of these is protected by the undissolved portion on the outside from contact with the steam, and as a consequence, a large amount of nitrate of soda is left undissolved; the loss from this source is the cause that little favor has been extended to the process.

One of the greatest sources of inconvenience in the purification and export of nitrate of soda is the want of pure water all along the sea-coast. On the Pampas a brackish water is obtained by boring for a few yards, and this, although not agreeable, is yet drinkable; but at Iquique, which is the port whence almost all the nitrate of soda is shipped, no drinkable water is to be found; the whole supply being derived from the distillation of sea-water. There are two large distilleries established to supply the want in this respect. The water obtained is, however, too expensive an article to be used in quantities sufficient for the healthy sustenance of animal life, and the mules employed in bringing down the nitrate of soda to the port, obtain a supply only by bringing it down with them from the mountains. Their privations in this respect, and the consequent injury to healthy life, is one of the greatest obstacles to the cheap supply of nitrate of soda.

This salt, obtained by the method described, is now usually supplied in commerce in a condition of great purity; the foreign matters, including water, or the *refraction*, as these are collectively termed in commercial circles, seldom exceeding seven per cent., and being more generally below six per cent. The impurities consist principally of common salt and water, the latter being attracted from the atmosphere; but a small proportion of sulphate of soda and lime is also found in it, with variable quantities of sand. No other substance can be detected in the commercial article in sufficient quantity to influence its value; but the actual value of the salt is so high that it becomes a matter of importance to detect the proportion of impurities, however small in amount. The following rapid and effectual method of doing so is recommended for those who are unacquainted with the more delicate manipulations of analytical chemistry:—A small quantity of the sample—say one hundred grains—is weighed out, and dried in a water or oil bath until it no longer loses

weight. The difference will give the amount of water. Another quantity, about one hundred grains, is weighed out and dissolved in pure distilled water, a few drops of pure nitric acid added, and the liquid made up to a thousand grain measures with water. About a hundred grain measures of this solution are transferred to a glass tube, and tested by comparison with several dilute standard solutions of common salt, contained in similar tubes, by means of a solution of nitrate of silver. The amount of cloudiness in the precipitate is observed with great nicety, and by comparison with the precipitate observed in the standard solutions of common salt, the per centage of this substance in the sample tested may be ascertained with much exactness. A very important point to be observed in this method of testing, is to have the solutions so dilute that only a distinct cloudiness shall be produced by the addition of the silver salt. By attention to this matter very minute differences are readily observed.

The per centage of sulphate of soda is determined by a similar method, using hydrochloric acid to acidify the solution of the sample in place of nitric acid, and employing dilute standard solutions of sulphate of soda, to compare with the sample. The precipitation is effected with a few drops of a strong solution of chloride of barium; but while the indications of chloride of sodium afforded by a silver salt are immediate, the cloudiness produced by adding chloride of barium to sulphate of soda, contained in a large quantity of solution of nitrate of soda acidified, is not immediately perceptible to its full extent when the solutions are weak. It is therefore advisable to compare the results obtained with the standard solutions, and the sample tested, only after the lapse of some hours. With this simple precaution the estimation of the per centage of sulphate of soda is effected with great accuracy by the method described.

The sand is estimated by dissolving the salt in water, filtering the solution, and after thoroughly washing the filter paper, calcining the insoluble portion. The per centage of water, chloride of sodium, sulphate of soda, and sand, being subtracted from one hundred parts of the commercial sample, will give the per centage of pure nitrate of soda to a very close approximation.

Various methods of estimating the amount of nitrate by a direct process are practised; but accurate results are only obtainable by the exercise of considerable skill in analysis. These are described under the article, NITRATE OF POTASSA, page 735; and the same description will apply equally well to the estimation of nitrate of soda, with the simple alteration of the equivalent weight of the former to that of the soda salt; that is, by putting the equivalent weight of nitrate of soda—85—in place of 101, the equivalent of nitrate of potassa.

Nitrate of soda is distinguished from potassa-nitre by its deliquescent property, a character that renders it quite inapplicable to some of the purposes for which the latter is employed, as for instance to the manufacture of gunpowder. It is extensively employed in the manufacture of nitric acid, owing to its cheapness, and also because it affords nearly ten per cent. more nitric acid than the corresponding potassa salt. Its

principal consumption is in the production of nitric acid, and as a vehicle for conveying oxygen to the sulphurous acid of vitriol works, whereby it is converted into sulphuric acid. Of late years it has been used largely as a manure. The subjoined are analyses of the commercial salt; but besides the ingredients named, LEMBERT found also small quantities of iodide of sodium and iodate of soda:—

	Hoffstetter.	Lecanu.	Wittstein.
Nitrate of soda,	94.29	96.70	99.63
“ potassa,	0.43	—	—
“ magnesia,	0.86	—	—
“ lime,	—	trace	trace
Chloride of sodium,	1.99	1.30	0.37
Sulphate of potassa,	0.24	trace	—
Water,	1.99	2.00	—
Insoluble matter,	0.20	—	—
	100.00	100.00	100.00

The following table gives the amount shipped from Iquique, and which may be assumed to be the yield of the saliferous grounds of Peru.

SUMMARY OF NITRATE OF SODA SHIPPED AT IQUIQUE, JANUARY 20, 1859, TO DATE, IN QUINTALS:—

For	1857.	1858.	1859.
England,	143,873	109,809	204,775
France,	127,767	138,465	197,980
Hamburg,	69,810	48,601	158,057
Orders,	141,220	204,927	175,957
United States,	13,600	24,900	29,780
Austria,	7,720	—	—
Holland,	6,038	—	11,866
California,	3,577	—	6,200
Spain,	20,300	—	—
Sardinia,	2,225	—	11,570
Chili,	—	11,666	—
Peru,	—	155	103
Total,	536,150	538,523	796,288

PHOSPHATE OF SODA.—This salt has long been known as one of the constituents of urine, having been discovered in that fluid by HELLOT in 1737. It was not, however, sufficiently distinguished from other salts till a much later period, when it was examined and analysed by PROUST, ROUELL, and KLAPROTH.

It is most conveniently prepared by adding carbonate of soda to the solution of acid phosphate of lime, obtained by treating bone earth with sulphuric acid. The liquor should be maintained at a boiling temperature; and the carbonate of soda must be added as long as effervescence continues, or until the solution has an alkaline reaction. The effervescence is due to the escape of carbonic acid; the soda unites with the free phosphoric acid and with a portion of the acid of the superphosphate, while at the same time phosphate of lime, or a mixture of this and carbonate of lime, is precipitated. This insoluble matter is removed by filtration, and the liquor is then boiled down and allowed to crystallize. To obtain an additional quantity of the salt from the mother-liquors, it is necessary first to examine if these manifest an acid or an alkaline reaction. In the first case, more carbonate of soda must be added to restore the alkaline reaction, and the liquor again evaporated and set aside to crystallize.

If, on the contrary, too much carbonate of soda has been added originally, the crystals obtained will require to be washed, a fresh portion of the acid phosphate of lime added, the solution evaporated, and again allowed

to crystallize. To obtain good crystals of this salt, it is necessary that a slight excess of carbonate of soda be present. In operations on the large scale, when it may be advisable to economize the phosphate of lime, FUNCKE directs that the precipitate obtained on adding carbonate of soda be dissolved in nitric acid; sulphate of soda is then added, and the nitric acid is removed by distillation. The residue is then treated with water, when a solution of phosphate of soda is obtained, with a deposition of sulphate of lime.

Properties.—Phosphate of soda crystallizes in beautiful transparent colorless rhombohedral prisms terminated by four converging planes. The crystals are represented by the formula, $2 \text{Na O}, \text{HO}, \text{PO}_5, 24 \text{H}_2\text{O}$. Their taste is cooling and mildly saline, not unlike common salt. They are soluble in four parts of water at 60° , and in two of boiling water. Exposed to the air, the salt undergoes efflorescence, but this takes place only at the surface; beneath, the form and transparency are preserved. Heated, the crystals fuse in their water of crystallization, and then water passes off. But one equivalent of water for every two equivalents of soda is obstinately retained, and cannot be expelled, except at a red heat. When two equivalents are driven off, the salt acquires peculiar properties, different from those it originally possessed, being converted into pyrophosphate of soda. The cause of the change of property, according to GRAHAM, is that in the common or rhombic phosphate, the acid is united in the proportion of one equivalent with two of soda, and one of water in the capacity of a base, constituting a tribasic phosphate of soda and water; and that when the basic water is expelled by a red heat, the salt becomes a bibasic phosphate, composed of one equivalent of acid and two of soda, and, therefore, a totally different compound. Phosphate of soda, consisting of two equivalents of soda, one of acid, and twenty-five of water— $2 \text{Na O}, \text{HO}, \text{PO}_5, 24 \text{H}_2\text{O}$ —contains—

	Centesimally.	
Soda,	62.6	40.00
Phosphoric acid,	71.4	45.62
Water,	22.5	14.38
	156.5	100.00

The uses of phosphate of soda are principally in medicine, and in the laboratory of the chemist.

Physiological Effects.—This salt is an excellent saline cathartic, equal to the most esteemed of the neutral salts in this respect, and superior to them in the mildness of its taste. As a purgative, it is employed in the diseases of children and delicate persons in preference to other saline substances, on account of its slight taste and mild action. It is well adapted for febrile and inflammatory disorders. It is one of the substances which have been applied in cholera, to restore to the blood its deficient saline matters. On account of the phosphoric acid which it contains, it has been supposed to be especially applicable in those diseases in which there is a deficiency of phosphate of lime in the bones. It has also been administered in diabetes.—*Pereira*.

Ordinary phosphate of soda—the variety above described, is known in combination with one equi-

valent only of water, the salt having the formula $2 \text{Na O}, \text{HO}, \text{PO}_5$; and also with fifteen equivalents of water, represented by $2 \text{Na O}, \text{HO}, \text{PO}_5, 14 \text{H}_2\text{O}$.

Pyrophosphate of Soda— $2 \text{Na O}, \text{PO}_5$ —obtained by heating the simple phosphate, has already been mentioned. This is also known in combination with water, the crystallized salt being $2 \text{Na O}, \text{PO}_5, 10 \text{H}_2\text{O}$. **Metaphosphate of Soda**— $\text{Na O}, \text{PO}_5$ —is obtained by heating the pyrophosphate, and according to the degree of heat used in its formation, appears in three different forms, which, though the same in composition, possess different properties, as if the pyrophosphoric acid passed by a gradual transition into metaphosphoric acid.

Phosphate of Soda and Ammonia, or Microcosmic Salt, is a compound much used in the chemical laboratory in blowpipe examinations. It is prepared by dissolving six parts of common phosphate of soda, and one part of chloride of ammonium, by boiling with ten parts of water. As the solution cools the double phosphate separates in crystals, and by a second crystallization is freed from adhering chloride of sodium. In this salt one equivalent of soda in the common phosphate is replaced by ammonia, and the crystallized salt has the composition, $\text{Na O}, \text{NH}_4 \text{O}, \text{HO}, \text{PO}_5, 4 \text{H}_2\text{O}$.

When subjected to the action of heat the ammonia escapes with the water of crystallization, and a compound of similar composition to borax remains, that is to say, a compound which contains both a free acid and a readily fusible salt. It is preferred in some cases to borax as a solvent or flux in blowpipe operations, the beads which it forms with many substances being more beautifully and distinctly colored than those of borax.

BORATES OF SODA.—There are several combinations of boracic acid and soda, such as the monoborate, diborate, and quadraborate of the alkali; but the most important of them is the diborate, a salt which has been already described fully in Vol. I., page 346. *et sequitur*. Allusion may, however, be made here to another source whence boracic acid and diborate of soda may be made. This is the diborate of lime—boracite—which has been discovered in large quantities on the Western coast of America, and called after its discoverer, HAYES, *Hayessine*. It is met with in the Peruvian province of Tarapaca, near the port of Iquique, and in the same locality as that which produces the nitrate of soda in such abundance. It is imported in moderately large quantities into Liverpool. It is in the form of botroidal lumps, which, when broken, appear in loose fibres or scales of a nacreous white color, intermixed or incrustated with crystals of carbonate of lime and finely divided white clay. Diborate of soda may be prepared from this mineral by reducing it to an impalpable powder, and dissolving in ordinary hydrochloric acid, filtering or clarifying the solution by subsidence, and adding carbonate of soda to the menstruum. The lime is separated by this process as carbonate, whilst diborate of soda is produced, and may be obtained from the filtrate or supernatant liquid by evaporation, *et cetera*.

CARBONATE OF SODA.—This important salt is met with in nature under various conditions, but never in a state of purity. It exists in the soda lakes of Egypt and

Hungary, and in other mineral waters, though not in sufficient quantities to remunerate for its extraction. KUHLMANN and VOGEL found it in admixture with the sulphate of the same base in an efflorescence on the walls in several towns, and considered its production to be owing partly to the presence of soda salts in the limestone used in the preparation of the mortar, and partly to the soda in the coal with which the limestone had been burned. In plants growing on the sea-shore oxalate of soda exists, and when these are burned, the oxalate, losing carbonic oxide, becomes carbonate.

Preparation.—In a state of purity, carbonate of soda is most conveniently prepared from the bicarbonate. To obtain it, the latter salt is washed with cold water until the filtrate, after being acidified with nitric acid, is not rendered turbid by chloride of barium or nitrate of silver. The washed salt is then dried, and by gentle ignition one half of the carbonic acid is expelled, and the pure neutral carbonate remains.

The bicarbonate of soda used should be as pure as can be obtained, and must, of course, be completely soluble in water. That most suitable is obtained by passing carbonic acid into a strong aqueous solution of crystallized carbonate of soda.

The process recommended by GAY-LUSSAC, for the preparation of pure carbonate of soda, is also a good one, and less troublesome than the former. He washes the ordinary commercial crystals of this salt with cold water; dissolves them in hot water, and cools the solution rapidly by surrounding it with cold water, stirring it all the time with a spatula, so that small crystals may be formed. These are to be collected on a funnel, and after the mother-liquor has been drained off, washed with cold water till the drainings mixed with excess of nitric acid no longer give a precipitate with nitrate of silver. The crystals are then to be dried, and when heated to low redness, the pure anhydrous carbonate remains.

Properties.—Anhydrous carbonate of soda is white, translucent, of specific gravity 2.4649; it is very soluble, and much more so in hot than in cold water; its reaction is alkaline, and its taste slightly caustic, much less so than the corresponding salt of potassa.

The annexed table shows the amount of the anhydrous salt contained in *solutions of different gravities at a temperature of 59°*:—

Specific gravity.	Per cent.	Specific gravity.	Per cent.
1.1816	14.880	1.0847	7.440
1.1748	14.503	1.0802	6.768
1.1693	14.136	1.0757	6.396
1.1648	13.764	1.0713	6.324
1.1594	13.392	1.0669	5.972
1.1549	13.020	1.0625	5.580
1.1500	12.648	1.0578	5.208
1.1452	12.276	1.0537	4.836
1.1404	11.904	1.0494	4.464
1.1356	11.532	1.0452	4.092
1.1308	11.160	1.0410	3.720
1.1261	10.788	1.0368	3.348
1.1214	10.406	1.0327	2.976
1.1167	10.041	1.0286	2.504
1.1120	9.672	1.0245	2.232
1.1074	9.300	1.0204	1.850
1.1028	8.928	1.0163	1.488
1.0982	8.556	1.0121	1.116
1.0937	8.184	1.0081	0.744
1.0892	7.812	1.0040	0.372

Carbonate of soda forms several crystalline com-

binations with water. When a saturated aqueous solution is evaporated at a boiling temperature, small crystals are deposited containing an equivalent of water, and consequently represented by the formula, $\text{Na O, CO}_2 + \text{HO}$. Monohydrated crystals are also formed when the ordinary commercial crystallized carbonate is kept in solution for some time in its own water of crystallization, or evaporated between 167° and 190; and when commercial crystals are exposed to the air at a temperature of 100°, the monohydrated carbonate remains as an effloresced mass. The form of the crystals is that of a four-sided table. It does not melt when heated, but at a temperature from 188° to 212° loses the whole of its water. Exposed to the air, it gradually absorbs moisture, to the amount of six or seven equivalents.

When ordinary crystallized carbonate is exposed to the air at a temperature of 54°, an effloresced salt remains, containing five equivalents of water, $= \text{Na O, CO}_2 + 5 \text{HO}$. This may also be obtained in crystals by melting the same salt and maintaining it at a temperature of 92°. PERSOZ states that crystals having this composition were accidentally obtained at the Buxweiler soda works, in transparent rhombic octohedrons, which effloresced slightly in the air, and when dissolved in water, and evaporated at 86°, again yielded the same salt. According to MITSCHERLICH, a solution of protosulphide of sodium exposed to the air, and frequently also a mixed aqueous solution of chloride of sodium and carbonate of potassa, yield crystals containing six equivalents of water, $\text{Na O, CO}_2, 6 \text{HO}$.

Crystals of carbonate of soda have also been obtained containing eight equivalents of water, $\text{Na O, CO}_2, 8 \text{HO}$, in the form of rectangular prisms, terminated by four-sided summits. These are produced when the ordinary crystallized salt cools from a state of fusion, or from a saturated aqueous solution at a particular temperature.

Common commercial crystallized carbonate of soda contains a still greater proportion of water than the salt last named. These crystals are a combination of one equivalent of carbonate of soda with ten equivalents of water, and are consequently represented by the formula $\text{Na O, CO}_2, 10 \text{HO}$. They are formed from a moderately concentrated solution, at a temperature below 92°. Their crystalline form is that of the oblique prism.

When gently heated this salt fuses, monohydrated carbonate crystallizes out, and the residual liquid, although containing more than ten equivalents of water to each equivalent of carbonate, solidifies at about 92°. When exposed to the air it loses a portion of its water, and becomes covered with an efflorescence containing eight equivalents of water.

NATIVE SODAS.—In France, Spain, and other countries where common salt is scarce, or where the duty upon this article is so great as to prevent its conversion into carbonate of soda, plants and alkaline waters are extensively consumed for the soda they contain. Besides these two great sources, carbonate of soda also occurs mineralized in some countries, though not in any great quantity, and is generally the residue of the evaporation of alkaline waters.

In Egypt, in the desert of Thiaï, to the West of the Delta, there is a pit four leagues long and a quarter of a league wide, which, during the winter months, becomes filled to the height of five or six feet with violet-colored water. In the summer this water evaporates, and an incrustation of carbonate of soda remains, half an inch in thickness. At Shegedin, in Little Curmania, a province of Hungary, WERNER found carbonate of soda as an efflorescence on the ground, and some years ago it was extensively collected and purified. The commercial demands for soda were supplied formerly, principally by the combustion of marine vegetals. These contain the soda, according to DUMAS, as oxalate, and by calcination this is converted into carbonate of soda. The plants, after being dried in the air, are burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semifusion, so as to concrete on cooling into moderately compact cellular masses. The substance so obtained is known under various names, according to the country whence procured, and the kind of plant consumed for its production. Among these may be mentioned the *barilla*

of Spain, *kelp* of Scotland, *varac* of Brittany and Normandy, *blanquette* of Frontignan and Aiguemorte, and the *salicor* of Narbonne. The soluble portion of the ashes consists of carbonate, sulphate, and hyposulphate of soda, sulphide, iodide, bromide, chloride, and ferricyanide of sodium, and sometimes also the corresponding compounds of potassium; and the matters insoluble in water are carbonate and phosphate of lime, sulphate of calcium, magnesia, alumina, silica, sulphide of iron, and charcoal. Of the several varieties, *barilla*, known also in commerce as Alicante soda, Carthagena soda, and Malaga soda, is by far the most valuable. It contains from fourteen to twenty per cent. of soda in the state of carbonate. It has a greyish-blue color, and when exposed to the air for some time effloresces at the surface. It is hard and difficult to pulverize, and has a pungent alkaline taste. The plant yielding the ash is the *salsola soda*; it is carefully cultivated on the coasts of Spain for the purpose of this manufacture. The following table shows the composition of various kinds of ash, as given by GIRARDIN, RICHARDSON, and others:—

Constituents.	Alicante.	Cherbourg.	Cherbourg.	Unknown.	Unknown.	Spain.	Villette.	Granville.
Sulphate of potassa,	—	22.19	42.54	18.80	22.00	15.85	20.35	13.50
Chloride of potassium,	—	16.00	19.64	—	—	10.55	10.53	15.00
Chloride of sodium,	65.00	45.78	25.38	73.20	68.00	68.35	54.11	65.00
Carbonate of soda,	2.00	9.53	3.71	6.00	6.00	traces	13.76	22
Sulphate of lime,	—	—	—	—	—	1.10	—	—
Insoluble matters,	3.00	1.50	.73	—	—	—	—	—
Iodine compounds,	—	traces	traces	traces	traces	—	traces	traces
Sulphate of soda,	30.00	—	—	—	—	—	—	—
Water,	—	5.00	8.00	2.00	4.00	4.00	1.25	5.00
Loss,	—	—	—	—	—	.15	—	—
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Kelp, which was formally prepared on a considerable scale on the coasts of Ireland and the Western coasts and islands of Scotland, is greatly inferior in value to *barilla*. This is the residue of the combustion of seaweeds and various species of *fuci*, and similar plants. Its composition is very variable, not only as regards the proportion of alkaline carbonate, but of the other constituents; and hence the uncertainty that attended its employment in some of the chemical arts, and particularly in the manufacture of crown glass. Two specimens—the first from Heisker, the second from Rona, both in the Isle of Skye—analysed by URE, gave the following results:—

Soluble	Sulphate of soda,	8.0	19.0
	Soda as carbonate and sulphide, ..	8.5	5.5
	Chlorides of potassium and sodium, ..	36.5	37.5
		53.0	62.0
Insoluble	Carbonate of lime,	24.0	10.0
	Silica,	8.0	—
	Alumina, with a little oxide of iron, ..	9.0	10.0
	Sulphate of lime,	—	9.5
	Sulphur and loss,	6.0	8.5
		100.0	100.0

The native sodas obtained in France are distinguished under various terms, according to the district where extracted. The most valuable is that known as *salicor* or *Narbonne soda*, which is the residue of the combustion of the *Salicornia annua*. It contains from fourteen to fifteen per cent. of the alkaline carbonate. Another kind, also valuable, is *blanquette* or *aiguemorte soda*, extracted

from plants growing on the coasts, among which the most important are the *Salicornia europæa*, the *Salsola tragus*, the *Atriplex portulacoides*, the *Salsola kali*, and the *Statice limonium*. The first-named of these yields the most soda, and all contain abundance of common salt. The amount of carbonate of soda in *blanquette* varies from three to eight per cent. *Varac* or *Normandy soda*, like *kelp*, is the ash of plants belonging to the species *fuci*. This is the least valuable of the French native sodas, but it contains much sulphates of soda and potassa, chlorides of sodium and potassium, and a little iodide of sodium. It is principally extracted for the sake of its potassa salts, and is used in the manufacture of glass and saltpetre. It is also valuable as a source of iodine. The commercial demands for soda are now supplied almost exclusively by an artificial method of production. *Barilla* and *kelp* are used to a small extent in the soap manufacture, as a substitute for chloride of sodium, and in Scotland seaweeds are still consumed as a source of potassa and of iodine. For the extraction of these the lie obtained from the ash is evaporated, when the potassa and soda salts separate one after the other, and the mother-liquor, distilled with sulphuric acid and peroxide of manganese, yields the iodine.

Generally, the ash of sea-plants, compared with that of those growing on the shore, is not rich in carbonate of soda, but contains much potassa. This fact is not, however, without exceptions, for in the various species of *fuci* soda largely predominates, and the fucoidal

plants are, doubtless, also the principal sources of iodine in those ashes.

Artificial Soda.—Soda Ash.—White Ash.—

The production of artificial soda is now one of the most important branches of manufacturing chemistry, although the art was, little more than half a century ago, almost entirely unknown. It may indeed be averred, without fear of contradiction, that since the first application of chemical science to manufacturing operations, few discoveries have been made having such an important bearing, whether considered in relation to social life, to commerce, or to the progress and successful prosecution of the useful arts, as that of the production of carbonate of soda from common salt. It would, indeed, be difficult to exaggerate the immense importance of this manufacture; and probably no more striking proof of this can be given than the enormously increased consumption of this salt since its production at a moderate cost was effected.

The manufacture of soap and of glass; the fictile arts, as well as those of bleaching and dyeing; the production of paper; many metallurgical operations, *et cetera*—are dependent for their successful prosecution upon a supply of carbonate of soda, and the various other substances obtained as by-products in the manufacture; and to meet the consumption of this article, the transformation of chloride of sodium or common salt into carbonate of soda is almost entirely depended upon.

Historical Notice.—It has been already observed that the introduction of artificial soda dates only from a very recent period. It has also been previously mentioned that of all the varieties of native soda, that known as *barilla* is by far the most valuable, containing twenty-five to thirty per cent. of the carbonate. The plant yielding this ash grows most luxuriantly on the coasts of Spain, and was formerly cultivated on a most extensive scale for the purposes of this manufacture; and the ash was produced so abundantly as to supply, not only the native demand, but also that of other countries where either the plants yielding soda were scarce, or if a large quantity of ash was obtained, the amount of soda contained in it was comparatively small.

While it thus happened that other nations were almost entirely dependent upon Spain for a supply of soda, Great Britain produced large quantities of native soda under the form of *kelp*, the manufacture of which was carried on at a very early period on the North and West coasts of Ireland, and later on the Western shores and islands of Scotland. This branch of trade was especially brisk at the commencement of the present century when, to meet the exigencies of the war, high duties were imposed upon the Spanish *barilla*. The annual rental of the kelp shores of the island of North Uist alone amounted at this time to seven thousand pounds; and at one period the entire quantity of *kelp* produced in Scotland, and its adjacent islands, was estimated at more than twenty-five thousand tons annually. Still, the quantity of native soda thus obtained was not sufficient to supply the demands of commerce; and even in 1834, some years after the introduction of artificial soda, *barilla* was imported to the amount of upwards of twelve thousand tons. But more especially was France dependent upon Spain for supplies of

native soda; and when at the time of the French revolution of 1789, during the cessation of the commercial intercourse between France and Spain, the importation of *barilla* was suspended, the National Convention, incited by the proposition of a manufacturer of the name of CARNY, made, in a special proclamation, an appeal to the chemists of France to devise a process by which common salt might be rendered available as a source of soda, and to lay before them whatever plans they knew or could devise for the preparation of soda.

Not only was the importation of *barilla* discontinued, but the supply of potassa was also greatly diminished at this period. All the potassa that could be obtained in France was immediately applied to the production of saltpetre to be consumed in the fabrication of gunpowder; and those branches of trade requiring for their prosecution large supplies of alkali—either potassa or soda—were almost completely at a stand still. But necessity is ever the mother of invention; and the republic mastered the difficulty by an unprecedented development of internal power. To the appeal of the Convention due response was made, and numerous plans were proposed; but of all the processes communicated to the committee intrusted with the examination and execution of the various proposals, the only one deemed likely to be advantageous was that of LEBLANC, and the justness of this decision has been ratified by fifty years' experience; no essential improvement having since been made in the process. The first establishment for prosecuting the manufacture on a large scale, was erected in 1804 at Saint Denis by LEBLANC, and was carried out by him and his partners, DIZÉ and SHÉE. The great French chemist, after having spent all his means in perfecting his plan, was neglected by the government of his own country, and though handsomely rewarded by the British government, at last died in an hospital. In Greece and at Rome statues have since been erected to his memory.

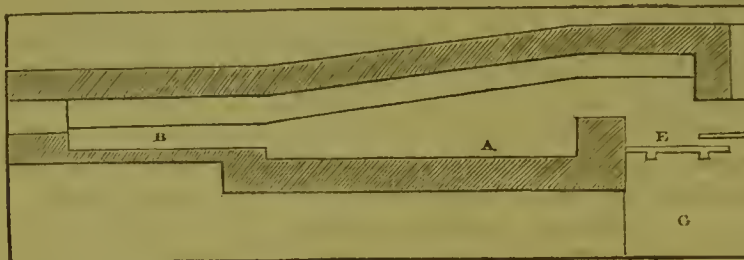
The valuable properties possessed by carbonate of soda were too well known, even at an early date, in England, to allow experimenters to remain idle. In a patent granted to Dr. BRIAN HIGGINS as early as 1781, the Editor finds that he started with common salt, which he decomposed into sulphate of soda and hydrochloric acid by oil of vitriol, in the manner described under SULPHATE OF SODA. The dry sulphate or salt cake obtained was put into a reverberatory furnace, with one-eighth of its weight of coal, and heated till the ingredients were melted, and the sulphate reduced to the state of sulphide. At this stage twice its weight of lead was introduced, and when the metal was melted, the whole was stirred with an iron rod until the sulphur united with the lead, and the fused caustic soda floated in a distinct layer over the surface of the sulphide of lead. The furnace was then tapped to allow the alkali to flow out.

The great expense attending this plan, arising from the high price of lead, *et cetera*, rendered it valueless as a commercial process; but in the same patent HIGGINS states that iron introduced into the furnace, or other metallic oxides, may be used equally well. Here, therefore, is clearly developed the principle of LEBLANC's

process, who merely replaced the *oxide of iron by oxide of calcium* or lime. HIGGINS, therefore, may be considered the *inventor* of the process.

LEBLANC'S process, is substantially that practised in Great Britain at the present day. Its introduction into this country was, however, effectually prevented until a considerable period after it began to be adopted in France, by the enormously high duty imposed upon salt, amounting, from the year 1805 until about 1822,

Fig. 516.



to fifteen shillings per bushel, or about thirty times the cost of the salt. Shortly after the repeal of this impost, the manufacture was commenced on a considerable scale in England by Mr. JAMES MUSPRATT of Liverpool—*vide* SOAP, page 872. Until the year 1830, the soda produced, which was almost wholly consumed in the soap manufacture, was disposed of in the crude condition, under the form of *black ash*. After that period the carbonate of soda was extracted from the black ash produced by lixiviation, and sold, as at present, as a white or soda ash. For about six years after the commencement of the manufacture, the trade remained almost entirely in the hands of the Editor's father. In the year 1836 an important improvement was effected in the carrying out of the process, by the introduction, by Mr. GOSSAGE, of an apparatus for condensing the gaseous hydrochloric acid eliminated during the conversion of the common salt into sulphate of soda.

Many other improvements have been subsequently made, tending to render the process more complete and economical. These will be described in detail in the following pages. The first important operation in the manufacture—the conversion of chloride of sodium into sulphate of soda—has already been fully discussed. The next operation in the process is the production of *black ash*.

Black Ash.—Ball Soda.—The materials used in the production of this ash are perfectly dry sulphate of soda, charcoal, or small coal—*slake*—and carbonate of lime, either in the form of common limestone or as chalk. These substances require to be brought into a state of fusion together, and this operation is the most important part of the whole soda process.

The details of the furnace arrangements at present in use for this operation are shown by the annexed

drawings. Fig. 516 is a longitudinal section; Fig. 517, 517½ a plan; and Fig. 518 an end elevation. The furnace is similar in construction to a common reverberatory; but its floor, or *bed*, is divided into two parts, A and B—Fig. 516—B being raised half a brick above A. The former, or that farthest from the fire, is termed the *preparatory bed*, and upon this the material is first placed and heated to low redness, so as to avoid cooling the furnace; the mass is often indeed in a state of partial fusion before its removal to the other hotter portion of the furnace bed, A. The latter is called the *fluxing bed*, and here the material is speedily brought to a fusion condition; the floor of A is lined internally with the most refractory fire-bricks that can be procured; it is not necessary to be so particular in respect to the floor of B. The arched roof is likewise built with fire-bricks. E is the fire space, G the ash pit, and F the flue leading to the chimney.

When economy of space is a matter of much moment, the opening to the fire space is on one side of the furnace, and the bars reach across; but when it can be allowed, it is preferred to have two sets of fire bars, as shown in Figs. 517, 517½, and 518, and to fire the furnace at the end.

There are two openings into the furnace, C and D.

Fig. 517.

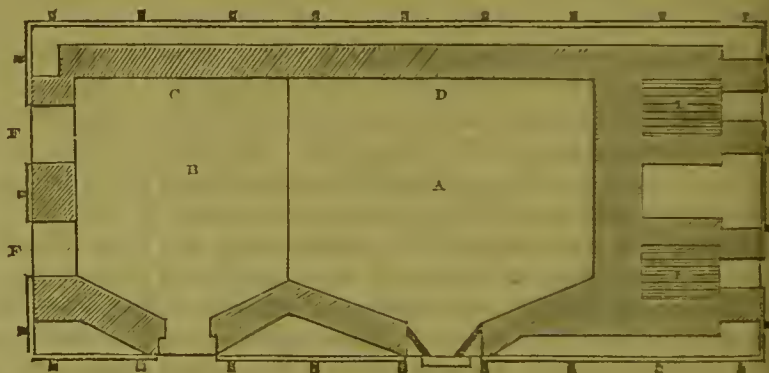
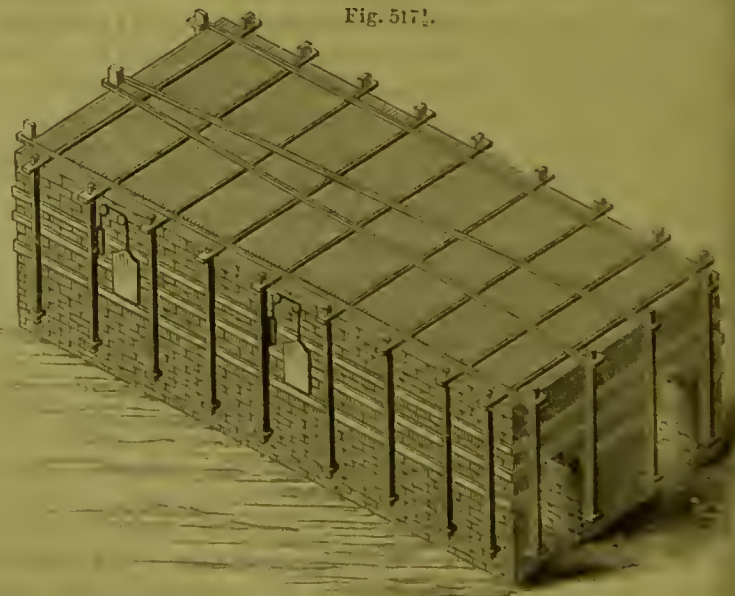


Fig. 517½.

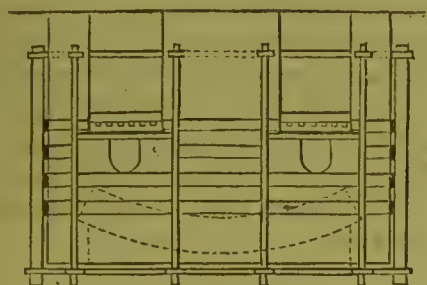


furnished with doors partially supported with weights passing over pulleys.

The walls of the furnace at C and D are bevelled off on the inside, so as to render the furthest parts of the furnace readily accessible by means of the iron rakes and utensils used in working it.

Immediately in front of the openings, C and D, is

Fig. 518.



suspended from the top of the furnace a stout iron rod, with a depression in the centre, so that the heavy rakes used may be supported upon it as a fulcrum.

The furnace walls are strengthened by iron plates, and firmly bound together by iron rods, as seen in the plan and end elevation.

The furnace having been heated to a suitable temperature, a charge, usually consisting of three hundredweights of sulphate of soda, three to three and a quarter hundredweights of crushed limestone or chalk, and two hundredweights of small coal, called *slack*, roughly mixed together, is then thrown on to the upper bed, A, and spread over it, so as to be evenly exposed to the flame of the furnace. A most important consideration is to have the ingredients of the mixture in proper proportions; although in compounding it, manufacturers may advantageously vary the amount of the ingredients, according to the purposes to which the black ash is to be applied. For instance, it is in some cases desired that the black ash produced should yield a considerable proportion of caustic soda, whereas in others, especially when the object of the manufacture is the production of soda crystals, the presence of caustic soda in large quantity is the occasion of great inconvenience.

It is a most difficult task to lay down precise rules for the guidance of the practical man in such cases, owing to the great difference in the materials used by different manufacturers. If the carbonate of lime employed be very fine, the proportions directed to be employed by *LEBLANC* yield a good black ash. These are a thousand parts each of dry sulphate of soda and chalk, and five hundred and fifty of charcoal.

Wood charcoal can rarely be obtained cheaply enough to be used for this purpose, and small coal, such as leaves but little ash, is substituted for it, in which case the quantity used should then be two-thirds of the weight of the salt cake, or even more.

If all the materials taken were perfectly pure the proportions required would be—of sulphate of soda forty-one parts, of carbonate of lime forty-four, and of charcoal fifteen. This accords with the explanation of the process of decomposition given by *DUMAS*; but his theory, as will be shown presently, has been more than once called in question. The proportions of salt cake and limestone or chalk employed, are properly one

hundred parts of the former to one hundred and five, or one hundred and ten, or even one hundred and twenty of the latter; while, as to the proportion of coal, probably not two manufacturers in this country use the same. *URE* recommends ten parts of salt cake, from eleven to twelve parts of chalk or limestone, and five parts of coal; and in a large manufactory near Liverpool, the proportions taken are, thirteen parts of salt cake, nine and a half parts of coal, and fourteen parts of limestone. Some chemists recommend that the materials should all be reduced to coarse powder, and afterwards most intimately mixed by sifting together. This is an unnecessary expense and waste, as the decomposition proceeds quite as successfully when the materials are simply broken into small fragments and mixed in that state.

The operation of fluxing is carried on in the following manner:—The furnace having been properly heated, the charge, differing in quantity according to the dimensions of the furnace, is thrown in upon the preparatory bed, spread evenly over its surface, and when it has become hot, transferred to the fluxing bed by means of an iron spatula or *slice*, shaped somewhat like an oar. The door of the fluxing bed is then closed, so that the heat may exert its full power, and a second charge is immediately placed upon the preparatory bed.

In a short time the charge upon the fluxing bed begins to soften at the surface and form into clots; it should then be turned completely over by the slice, and a fresh surface exposed, until the whole mass appears to have the consistence of dough. Jets of inflamed sulphide of hydrogen and carbonic oxide gases now issue from the various parts of the mass, and the whole should be continually worked about with the slice and an iron rake, so as to equalize the mass, and continually expose fresh surfaces to the action of the fire. When the jets of flame begin to disappear the mass is raked out into iron barrows, each capable of holding a single charge, in which it is allowed to solidify, and in this state it is termed a *ball*. In a furnace of the dimensions above given, the weight of each charge would be about seven hundredweight. Nine of these, the weight of which after decomposition will be about five hundredweight, may be introduced and withdrawn in eight hours, or twenty-seven in twenty-four hours. This is, indeed, the quantity usually worked in that period, but a still greater number of balls may be produced in the same time. The Editor has known nine charges to be introduced and completely decomposed in five and a half hours, and it is important to notice that the black ash so produced yielded its soluble portion with far greater ease than a ball that has remained in the furnace some minutes longer. It is, indeed, important that black ash should be withdrawn from the furnace the moment decomposition is completed, for in this case the mass, after solidification, remains so porous that the soluble portion may be extracted with colder water, and in a shorter period of time, than when closer and heavier black ash is produced. This is one of the characteristics of good black ash; another is that it should contain no sulphate of soda, and more especially should it be free from sulphide of sodium. It should be of a blackish-grey color;

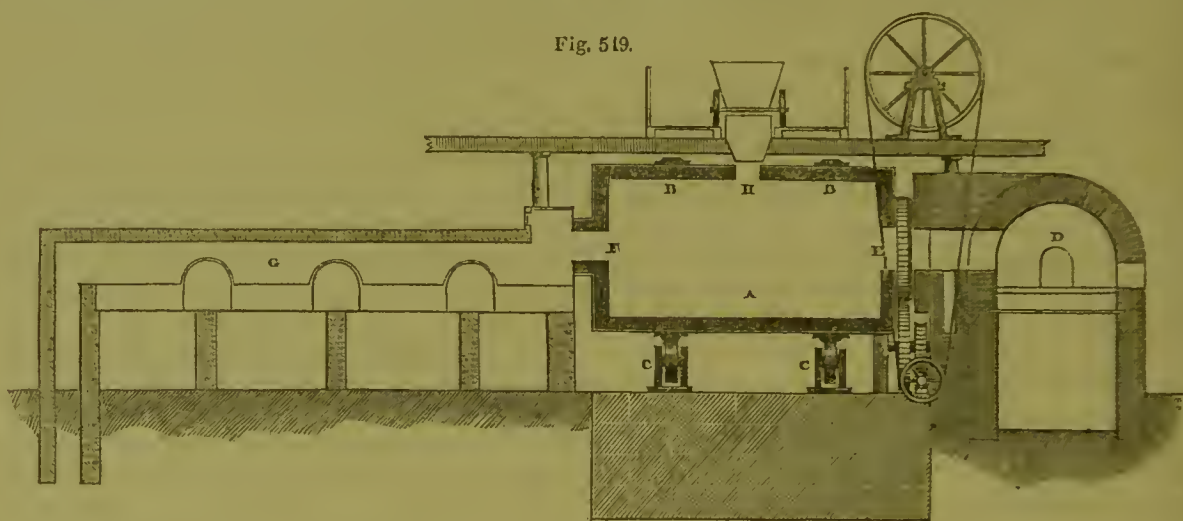
when treated with water the filtrate should be colorless, or with the slightest green tinge; and should yield about twenty-four per cent. of available alkali.

A patent was obtained in 1853 by ELLIOT and RUSSELL for an improved furnace, to be used in place of the usual black-ash furnace. This improvement consists in the substitution of a revolving cylinder of iron, lined with fire-bricks, for the chambers of the ordinary furnace, and with the later modifications by Messrs. STEVENSON and WILLIAMSON, of the Jarrow Chemical Works, South Shields, Newcastle-on-Tyne. Its advantages appear to be of sufficient importance to induce its general adoption by soda manufacturers.

In the annexed drawing—Fig. 519—A is the cylinder made of malleable-iron plates, lined with fire-bricks, some

portions of the lining being made to project in the form of shelves beyond the inner periphery of the brick cylinder, the shelves being intended to assist in mixing the charge. The malleable-iron cylinder is formed in two cast-iron rings, B B, which rest and run upon strong iron rollers, C C, supported in proper bearings. The cylinder is made to revolve slowly by means of a pair of pulleys and a train of wheels, as shown in the figure. The internal dimensions of the cylinder are—length thirteen feet, and diameter seven feet; D is the coal-burning furnace, from which flame escapes through a lateral orifice, corresponding with openings, E F, in the ends of the cylinder; and the flame, having traversed the chamber of the furnace, passes over the contents of a boiling-down pan, G, to the chimney.

Fig. 519.



When it is desired to charge the cylinder, the aperture, II, is raised to the position shown in the figure corresponding with a hopper containing the charge, and the charge is at once introduced. When the working of the charge is finished, the aperture, II, being unstopped, and the position of the cylinder reversed, it is run into a number of iron waggons, linked together, and brought consecutively under the aperture. With a cylinder of the above-stated dimensions the proper charge contains twenty-four hundredweights of sulphate of soda, with the usual proportions of chalk and small coal.

According to the invention of STEVENSON and WILLIAMSON, as described in their specification, the chalk is first introduced into the cylinder with a portion of the coal, and heat is applied from the coal furnace. During this period, which continues about an hour and a half, it is only needful to cause the cylinder to revolve about once in five minutes, and the same rate of speed is sufficient until the decomposition of the charge approaches completion, when it is found necessary to increase the number of revolutions to the rate of one in two minutes. The effect of the previous heating of the chalk and coal is to convert the greater part of the chalk into caustic lime. When this is effected, the charge of sulphate of soda with the remaining portion of small coal is added; and the rotating motion, together with the application of heat, being continued during a further period of about an hour, the decomposition is completed, and the charge

is ready for withdrawal. In this manner the furnace works off a charge every three hours, or decomposes nearly ten tons of sulphate of soda per diem, which is almost equal to the work of three ordinary black-ash furnaces.

The patentees state the advantages resulting from their improved furnace and mode of working to be—

1. The continual motion of the furnace causes its contents to become heated with perfect uniformity, so that no part of the charge ever attains an excessive temperature, and thus the loss of soda from volatilization is much diminished.

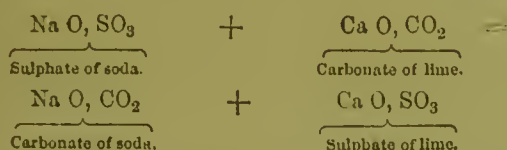
2. The mixing of the materials for the charge is effected without requiring the furnace to be opened for the introduction of implements, consequently without a current of air being drawn through the furnace during such mixing, thus providing for the atmosphere in the furnace being constantly devoid of free oxygen.

3. From the much larger quantity of work effected by the patent furnace at one time, a smaller number of skilled workmen is sufficient, and the risk of bad work is diminished, and a more complete decomposition of the sulphate of soda is insured by the more perfect mixing.

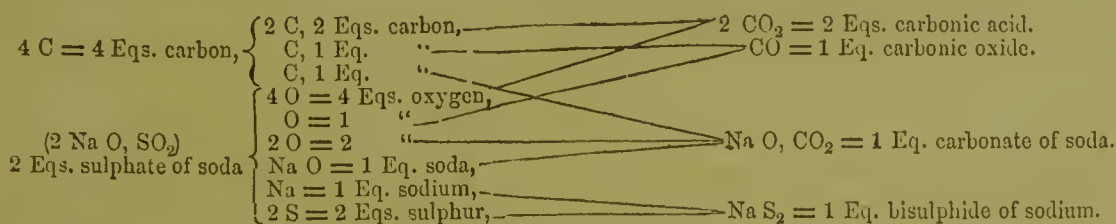
4. The waste of soda by absorption into the beds of the ordinary furnaces is avoided, and no tools being used in the process of mixing, the surface of the brick lining is less subject to injury from working than the bottoms of reverberatory furnaces.

Theory of the Decomposition.—The conversion of

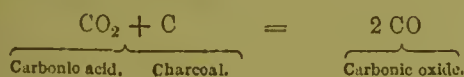
the sulphate into carbonate of soda by the above-described method of **LEBLANC** is a very complicated process of decomposition. Some French chemists, however, amongst whom **DUMAS** may be mentioned as the foremost, take a very simple view of the ease. They suppose that when sulphate of soda, carbonate of lime, and eharecoal are fused together in the proportions given above, in the first place the sulphate of soda and carbonate of lime react upon each other, producing carbonate of soda and sulphate of lime thus :—



The sulphate of lime, in contact with incandescant charcoal, yields its oxygen to the latter element, and carbonic oxide, or a mixture of this and carbonic acid is evolved, leaving protosulphide of calcium in admixture with the carbonate of soda previously produced.



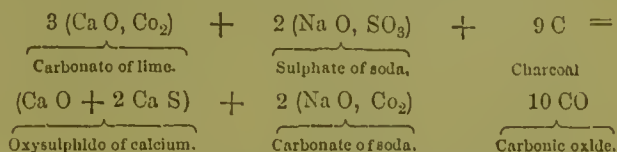
If carbon is present in greater proportion, it is taken up by the carbonic acid gas, which thereby passes into the state of carbonic oxide—



Supposing this to be a true statement of the transformations, the subsequent decomposition—namely, the reaction of carbonate of lime upon bisulphide of sodium—must also be far more complicated than is usually supposed. It is exceedingly difficult to arrive at any positive conclusion from the views of different chemists upon this subject. It is certain, however, that the calcination of sulphate of soda with both coal and carbonate of lime at the same time, is by no means essential to the process; if desirable, the sulphate might first be treated with coal alone, and the resulting sulphide or mixture of sulphide and carbonate be afterwards calcined with carbonate of lime.

Composition of Black Ash.—Probably in no other department of chemistry does a greater difference of opinion exist among theorists, than as to the true composition of black ash. The principal, but by no means the sole discrepancy in their statements, is found in their different views of the composition of the insoluble lime salt. When a mixture of sulphide of calcium and carbonate of soda in *equivalent proportions* is treated with water, insoluble carbonate of lime is formed, and sulphide of sodium is obtained in solution. But if to the mixture of carbonate of soda and sulphide of calcium a portion of lime be added, and the compound be then affused with water, the soda salt, partially

Other chemists take a different view of the decomposition. According to Gmelin, the sulphate of soda is reduced by the charcoal to the state of sulphide of sodium, with evolution of carbonic oxide gas; and the sulphide of sodium so produced is converted by the carbonate of lime into sulphide of calcium and carbonate of soda; and when three equivalents of carbonate of lime are used to two of sulphate of soda, the result is shown in the annexed equation:—



In the statement of the result of the decomposition, DUMAS and GMELIN agree precisely; they differ, however, as to the mode by which the result is obtained. LIEBIG shows the action of charcoal upon sulphate of soda to be far more complex than as stated by GMELIN, and gives the following diagram in elucidation of his views:—

deprived of its carbonic acid, alone dissolves, and the sulphide of calcium remains unaltered.

The question to be solved, therefore, is—in what manner does the free lime prevent the decomposition that would otherwise ensue? Many chemists explain the difficulty, by supposing that the lime— CaO —enters into combination with the sulphide of calcium. In the first place, however, it must be borne in mind that this supposed compound has never yet been isolated, so that its precise composition cannot, therefore, be ascertained.

DUMAS, and some others assume it to be a combination of two equivalents of sulphide of calcium with one equivalent of lime— $2 \text{ Ca S} + \text{Ca O}$. UNGER, reviewing DUMAS' theory of the process of its formation, considers it much more probable that it is a compound of three equivalents of sulphide of calcium with one equivalent of lime— $3 \text{ Ca S} + \text{Ca O}$ —a formula also assigned to it by PAYEN, and adopted by many others. ROSÉ regards it as composed of one equivalent of sulphide of calcium, with one of hydrate of lime— $\text{Ca S} + \text{Ca O, HO}$.

The conclusion that combination of sulphide of calcium with lime does ensue, appears to have been arrived at, not from an analysis of the pure compound, for, as mentioned above, it has never yet been obtained, but simply because, in the presence of free lime, the sulphide of calcium *does not dissolve* when treated with water. This is indeed the only argument stated by DUMAS to account for the existence of his $2\text{CaS} + \text{CaO}$; and certainly the fact that an additional proportion of lime in the preparation of black ash does render the sulphide of calcium more insoluble, seems a power-

ful argument for the existence of this or a similar compound. UNGER, however, reasoning analogically, argues that because ROSÉ obtained a salt having the formula $3 \text{ Ba S}, \text{ Ba O}, 28 \text{ HO}$, the compound— $3 \text{ Ca S}, \text{ Ca O}$ —though free from water, might also be supposed to exist. This, although affording a strong presumption, cannot be accepted as a conclusive proof; and still the question remains—If sulphide of calcium is more soluble in the presence of free lime than in the pure state, why is this the case? In an investigation into the composition of black ash performed a few months ago by Mr. J. W. KYNASTON in the Editor's laboratory, it was found that when the ash was treated with water, and allowed to remain for some time undisturbed, the lime previously existing in the ash in the free state, by acting upon the solution of carbonate of soda, eliminated caustic soda, *itself becoming wholly converted into carbonate*. This, if not conclusive proof of the non-existence of the hitherto assumed compounds of sulphide of calcium and lime, at least shows that the stability of the sulphide of calcium of black ash, when treated with water, is not to be ascribed to the production of any such compound. In this view Mr. KYNASTON is supported by the observations of GOSSAGE, than whom probably no one ever performed so numerous a series of experiments upon black ash, and more especially upon its insoluble portion. Mr. GOSSAGE states that he has long held this view, and, indeed, founded upon it a process for the recovery of the sulphur from the insoluble portion of the ash, to which further reference will shortly be made. Mr. KYNASTON suggests that, instead of the combination of sulphide of calcium with lime, a compound may exist of sulphide of calcium with carbonate of lime, and having the formula $2 \text{ Ca S}, \text{ Ca O}, \text{ C O}_2$. Were further evidence required, an additional proof that the whole, or at least the greater part, of the free lime of black ash is converted into carbonate, when the ash is treated with water, is the fact of the existence of so large a proportion of caustic soda in black-ash liquor, and the presence of which cannot be satisfactorily explained in any other way. Some chemists—indeed by far the greater number who have written upon the subject—do give hydrate of soda as a constituent of black ash. It will not, however, be difficult to show the fallacy of this. KNAPP accounts for the proportion of caustic acid, by supposing a portion of the carbonate of lime to be burnt and converted into the caustic state, before the decomposition of the soda salt is effected; the caustic lime, then acting upon the sulphide of sodium, produces sulphide of calcium and caustic soda:—



One may be permitted to doubt whether this reaction would take place under the circumstances. Carbonate of soda, treated in solution with caustic lime, gives rise to the formation of caustic soda and the insoluble carbonate of lime. But if caustic soda and carbonate of lime be fused together, carbonate of soda and caustic lime are produced. So if a mixture of caustic soda and sulphide of calcium be fused together, sulphide of

sodium and caustic lime are formed, $\text{Na O}, \text{ Ca S} = \text{Na S}, \text{ Ca O}$; but if the resulting mass be treated with water, caustic soda and sulphide of calcium are reproduced. It cannot be reasonably supposed, then, when in the case of the pure salts the above-mentioned reaction is well known to take place, in the preparation of black ash, exactly the reverse action should occur with the same salts and by a similar mode of treatment. Yet it is well known that in the preparation of black ash, caustic lime may be, and in the early days of the manufacture in this country was, instead of carbonate of lime. But in such a case a predisposing cause, if the term may be allowed, determines the reaction. When zinc and water are placed in contact, the water is not decomposed; but if an acid be added, decomposition of the water rapidly takes place. So when sulphate of sodium and lime are fused together no change occurs; but when charcoal is also present, and hot air is blown upon the mass in the reverberatory black-ash furnace, decomposition immediately follows.

Carbonic acid is here the *predisposing cause*, just as sulphuric acid is in the case of zinc and water. The success of this soda process is, indeed, in no small degree owing to the remarkable affinity of soda in the fused state for carbonic acid; and this is so great that even supposing caustic soda to exist in the black ash at any time during its preparation, it could not remain more than a few moments uncombined in the atmosphere so highly charged with that acid. It is further to be noticed that all those analysts who state hydrate of soda to be a constituent of black ash, also include *carbonate of lime* amongst the ingredients. But what an inconsistency to suppose that hydrate of soda and carbonate of lime can exist, after fusion together for such a length of time as in the preparation of black ash, when the two salts so readily decompose at a much lower temperature than that to which the mass is subjected. Still another argument against the existence of caustic soda in black ash presents itself, if the theory of DUMAS and others of the French school be accepted as the true one. These explain the reaction, by supposing that the sulphate of soda and carbonate of lime first decompose the bases, exchanging acids, and that the sulphate of lime so formed is afterwards reduced to sulphide of calcium by the charcoal. In this case *no caustic soda can have been formed*; and as carbonic acid once combined with soda cannot be again removed by simple heating, of course no caustic soda can be produced. In conclusion, the Editor must again assert, that as yet no sufficiently satisfactory proof has been put forward to show *hydrate of soda to be a constituent of black ash*: while, on the other hand, its existence in the black-ash liquors is quite consistent with the views expressed above. But if this be admitted, the theory that the sulphide of calcium owes its insolubility and permanence to its having entered into combination with free lime, is of course disproved. The fact does not indeed require such a far-fetched explanation. Protosulphide of calcium is itself *very insoluble*, bisulphide of calcium is *readily soluble*, and all that it appears necessary to guard against is the formation of bisulphide of cal-

cium, or rather perhaps of bihydrosulphate of lime, which is so liable to be produced.

Whether a sulphite and hyposulphite actually exist in black ash, is a question that hardly admits of proof. They are included in the analyses of several investigators, and the researches of Mr. KYNASTON certainly lead to the same conclusion. Still the probability of the formation of these, subsequent to the removal of the black ash from the furnace, *is so obvious, that until the point has been conclusively determined, it is better not to express any positive opinion.* Black-ash liquors certainly contain both salts. Sulphate of soda and ferrocyanide of sodium are frequently constituents of black ash, but these are not always present. The Editor has had numerous samples examined which were free from even a trace of either one or the other. The subjoined analyses of this highly complex mixture are by UNGER and RICHARDSON. Both, it will be seen, *assume* the existence of a compound of sulphide of calcium and lime, and also of caustic soda.

	From Newcastle. Unger.	From Newcastle. Richardson.
Sulphate of soda,	1.99	3.64
Chloride of sodium,	2.54	0.60
Carbonate of soda,	23.57	9.89
Hydrate of soda,	11.12	25.64
Carbonate of lime,	12.90	15.57
Oxysulphide of calcium (3 Ca S + Ca O),	34.76	35.57
Sulphide of iron,	2.45	1.22
Silicate of magnesia,	4.74	0.88
Charcoal,	1.59	4.28
Sand,	2.02	0.44
Water,	2.10	2.17
Loss,	0.22	—
	100.00	100.00

Mr. KYNASTON's analysis is also appended :—

Carbonate of soda,	36.879
Chloride of sodium,	2.528
Sulphate of soda,	0.395
Silicate of soda,	1.182
Aluminate of soda,	0.689
Sulphide of calcium,	28.681
Carbonate of lime,	3.315
Bisulphide of calcium,	0.435
Hyposulphite of lime,	1.152
Sulphite of lime,	2.178
Caustic lime,	9.270
Magnesia,	0.254
Sulphide of iron,	0.371
Sesquioxide of iron and phosphate of lime,	2.658
Alumina,	1.132
Charcoal,	7.007
Sand,	0.901
Ultramarine,	0.959
Water, hygroscopic,	0.219
	100.205

Annexed is another analysis of black ash, just made by Mr. MARTIN MURPHY, the Editor's talented assistant, and whose aid in scientific and literary matters for twelve years he has found of the utmost service :—

Soda,	25.388
Lime, chiefly existing as sulphide,	35.484
Carbonic acid,	17.599
Sulphur,	14.747
Sulphuric acid,	0.421
Iron,	3.020
Alumina,	1.165
Silicic acid,	0.945
Chlorine,	0.794
Charcoal,	5.724
Ultramarine and sand,	1.659

The preceding numbers correspond with the following order of combination :—

Carbonate of soda,	41.489
Sulphate of soda,	0.748
Chloride of sodium,	1.308
Aluminate of soda,	0.392
Silicate of soda,	1.162
Sulphide of calcium,	33.193
Caustic lime,	9.320
Carbonate of lime,	0.857
Sesquioxide of iron,	3.020
Alumina,	1.020
Charcoal,	4.724
Sand, <i>et cetera</i> ,	2.259

100.000

The characteristics of good black ash are as follows :—It should be of a blackish-grey color, and with open pores, similar to pumice-stone, so that a liquid may easily penetrate its substance. It should contain from twenty to twenty-four per cent. of available soda, and should be free, or contain only a slight trace of sulphate of soda. When the solution obtained by lixiviating a portion is acidified, merely a faint smell of sulphide of hydrogen should be perceptible.

Lixiviation of the Black Ash.—This is the next operation in the process of manufacture, and is the first step towards the preparation of pure soda from black ash. Its object is the separation of the soluble constituents from the calcareous and other insoluble matters present. To effect this the balls of crude soda, a day or two after preparation, are broken to fragments and thrown into iron vats. By some it is recommended, first, to crush or grind the ash under upright millstones, and afterwards to sift it, or else to crumble it by exposure to hot vapor. With this view, the ash is sprinkled with water in a tolerably hot furnace, where, in the atmosphere of vapor, it soon swells up and falls to pieces. If the ash has been properly prepared this proceeding is quite unnecessary, and indeed objectionable on other grounds than the expense and labor required. With ash that has been allowed to remain too long in the furnace it may, however, be necessary to heat it in such a manner, otherwise the extraction of the soluble ingredient occupies too long a period of time; and it must be borne in mind that the longer the liquor is allowed to remain in contact with the insoluble portion of the ash, or the *soda water*, the greater the amount of sulphide of sodium in the solution, and this must be subsequently got rid of, or the ash will be unfit for use.

The vats used in the process of lixiviation are of iron, and of considerable size, and are so arranged as to allow the separation of the soluble constituents of the ash with the smallest possible proportion of water.

But although, as KNAPP observes, it is desirable, on the one hand, to use as little water as possible, yet it is equally necessary on the other hand to dissolve out *every particle of alkali from the residue.* In this, as in all other similar cases, both objects have been obtained by one and the same ingenious method.

The difficulty is obvious; if too little water be used in the first instance, a portion will remain undissolved. In the contrary case all the alkali will be dissolved, but, as at first, the whole solution cannot be drawn off; for a considerable quantity is kept back by the spongy

residue. It is, therefore, impossible in any case to obtain the whole quantity of soluble matter with one portion of water; a second, third, and fourth portion will be required, each of which will contain a less quantity in solution, so that, altogether, there will be a vast excess of liquid. The contrivance by which this difficulty is overcome, depends upon an uninterrupted continuance of the process, and consists in using the same water which was employed for the first infusion, with fresh portions of crude ash, until the solution has acquired the proper strength for boiling.

Just in the same manner every second or subsequent infusion can be increased in strength, so that none but sufficiently concentrated lie is supplied to the evaporating pan. Suppose that a certain quantity of water has taken up eight per cent. from the first portion of the soda, it will take up as much more from the second, and leave it containing sixteen per cent.; from the third portion it will be drawn off with twenty-four per cent., and so on.

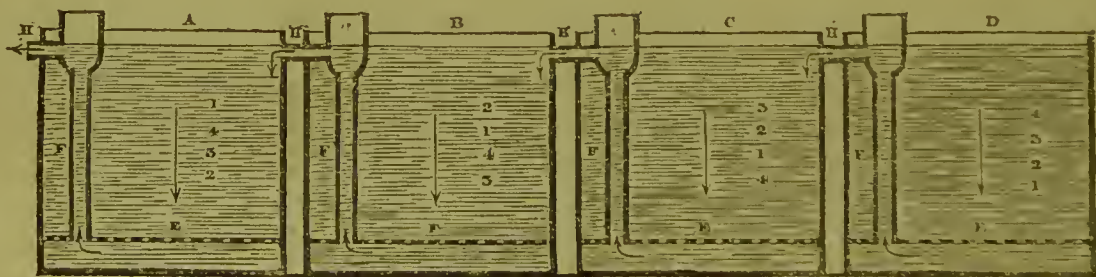
The lixiviation was formerly effected in vats so placed at different elevations, that weak liquors resulting from partly lixiviated ash flowed upon ash contained in a fresh set vat; but in using such apparatus, the manufacturer had to remove the partially lixiviated ash into higher vats, and yet the strongest liquors obtained rarely exceeded a specific gravity of 1150°, and consequently a very large quantity of water had to be evaporated to obtain dry salt. A very ingenious and scientific apparatus was invented and applied successfully by the celebrated French chemist, CLEMENT DESORMES. This apparatus provided for obtaining solutions of much higher gravity, but necessitated the employment of much manual labor, and also occupied a large space. The lixiviating apparatus which is now universally adopted by the manufacturers of soda in this country, the Editor knows to be a foreign invention, which was introduced

by Mr. C. T. DUNLOP into the St. Rollox Chemical Works, Glasgow, about the year 1843. This apparatus, from its extreme simplicity, correct scientific principle, and the perfect manner in which the lixiviation is effected by its use, appears to fulfil all the conditions which can be desired in this process.

The apparatus is represented in Fig. 520, and may be described as consisting of a rectangular vessel about twenty-four feet long by twelve feet wide, and five deep, having three partitions, *HH*, dividing it into four vats, *A*, *B*, *C*, *D*, of twelve feet by six feet. Perforated false bottoms, *EE*, are supported about three inches above the bottom of the vats, on which the black ash is thrown in lumps. Each vat is furnished with a vertical pipe, *F*, five feet long, the lower end of which is open, and communicates with the space below the false bottom. About one foot six inches from the upper end of this pipe a side branch is provided, and this branch is bolted to the side plate of the vat; an opening being made in the side plate, to correspond with that in the branch. By this means a communication is effected between the lower part of one vat, and the upper portion of another. The upper part of the pipe, *F*, is enlarged; and at the lower part of this portion, a conical seating is provided, which admits of the passage being closed by a plug, or of a short pump being applied to withdraw the fluid contents of the vat.

When in regular use, the four vats will contain black ash at various stages of lixiviation, diffused in their corresponding liquors—one being filled with fresh balls; and another, furthest distant from it in the series, containing residuum all but deprived of its soluble matter. A supply of warm water is run upon the first and nearly spent vat; and this, after permeating through the residuum and becoming impregnated with alkali, rises through the pipe *F*, and flows into the upper part of the second vat, through the contents of

Fig. 520.



which it passes, taking up more alkali, and rising again by a similar pipe, gains access to the third vat, and so on into the fourth vat, in which the liquor becomes fully saturated by its contact with the fresh balls. The flow of liquor from the last vat may be intermittent, but it is preferable that it should be continuous; the supply of warm water to the first vat being also continuous, and this vat kept constantly filled. When it is found that the liquor proceeding from the first vat contains scarcely any alkali, this vat is shut off from the series; and the remaining liquor being pumped out, the residuum is removed, and the vat filled with fresh balls. This vat now becomes the fourth of the series, and receives liquor from that which was previ-

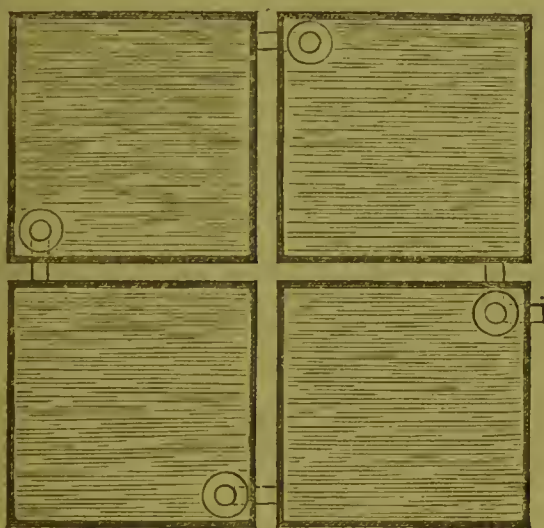
ously the fourth, by means of a pipe leading externally from the lower part of the latter to its upper part. When the vats are arranged in a square of four as shown in Fig. 521, in place of four longitudinally, this external pipe is not needed. In this manner each of the vats becomes consecutively the one to be discharged, and to be refilled with fresh balls.

In large establishments, a series of sixteen or more vats in a double row are employed, and these may be constructed by fixing longitudinal and transverse partitions in one large vessel.

By the provisions of this highly scientific apparatus, it becomes no longer needful to remove the black ash during the process of lixiviation; which removal was

previously attended with much labor, injurious exposure to the oxidising influence of the air, and great diminution of the permeability of the mass. The residuum in the above admirable arrangement, is constantly

Fig. 521.



supported by the fluid in which it is immersed, and thus kept in a condition highly favorable to its permeability; and the solvent is caused to percolate through the contents of the whole series without the cost of pumping. Practically, the advantages have been found to comprise a much more perfect abstraction of the soluble parts of black ash, and the obtaining of solutions requiring less than half the evaporation formerly necessary; indeed, so perfect is the process of lixiviation, that scarce one-tenth per cent. of soda is left in the residue.

In some alkali works, to assist the solvent power of the water employed in the lixiviation of black ash, it is usual to heat it to about 90° to 100° . This end may be conveniently attained by passing the water through a coil of pipes contained in a steam boiler. The practice of heating the water, though it undoubtedly aids the process of lixiviation, is nevertheless very objectionable, principally because sulphide of calcium is dissolved and decomposed by hot water, giving rise to the formation of sulphide of sodium, and the hotter the water the greater will this proportion of sulphide be, or rather of the double sulphide of sodium and iron contained in the vat liquor.

The temperature of the water, it must also be observed, always rises considerably— 20° to 30° or more—on coming in contact with the fresh black ash in the fresh vat, owing to the powerful affinity of caustic lime for that liquid to produce hydrate of lime. In summer the liquor frequently becomes so hot as to render necessary its withdrawal considerably below the point of saturation, otherwise the ash obtained on evaporation would be so strongly impregnated with sulphide, that it would be quite inapplicable to many purposes.

If the temperature of the liquor should not rise higher than from 110° to 120° , it may remain in contact with the ash until of specific gravity $1.225 = 45^{\circ}$ Twaddell; in the contrary case it should be withdrawn

at a density of $1.200 = 40^{\circ}$ Twaddell, or even still lower. Water is allowed to run into the weak vat until the density of the liquor passing through is reduced to 1.10 to $1.15 = 2^{\circ}$ to 3° Twaddell, and the insoluble matters remaining should, after being dried, contain not more than 0.2 or 0.3 of available soda. This last portion, if extracted, would contain so large a proportion of sulphate and other salts of lime, that on coming into contact with the ash in the next vat, it would decompose and render valueless more than an equivalent proportion of soda.

The composition of vat refuse—soda waste—according to UNGER's analysis is as follows:—

Carbonate of lime,	19.56
Oxysulphide of calcium, $3 \text{ Ca S} + \text{Ca O}$,	32.80
Sulphate of lime,	3.69
Hydrosulphite of lime,	4.12
Hydrate of lime,	10.69
Bisulphide of calcium,	4.67
Sulphide of calcium,	3.25
Sulphide of sodium,	1.78
Oxide of iron,	3.70
Silicate of manganese,	6.91
Charcoal,	2.60
Sand,	3.09
Water,	3.45

100.31

The sample of waste examined by UNGER must have been some time exposed to the air. When fresh it contains, according to the Editor's observations, *no bisulphide of calcium*, and but little hydrate of lime either free or in combination. The sulphate of lime also is wholly formed, subsequent to the removal of the soluble constituents of the ash. After being kept for some time only partially dried, a large quantity of sulphite and hyposulphite of lime is also produced, and the mass becomes of a dirty white color, with streaks of a beautiful blue color, running through it. The liquor containing in solution the salts of soda removed from the black ash, as it is withdrawn from the vats, is conducted into a series of settlers or iron vats. In these it is allowed to rest for some hours, to deposit any impurities that may be held in suspension. It is then pumped into a spacious cistern or reservoir, so elevated that, by means of pipes, the liquors may be distributed to the concentrating pans and furnaces.

EVAPORATION OF THE LIE.—The process of concentration is carried on in two different ways. Most commonly the solutions are evaporated and the residue calcined in the same reverberatory furnace, known as the *white-ash furnace*, whose extreme length should be about eighteen feet, and the breadth about nine feet. Its interior is lined with fire bricks, between which and the external masonry is placed a partition of sheet iron. By the application of heat in this manner, the evaporation proceeds rapidly, quietly, and at a very moderate expense of fuel. The waste heat from the black-ash furnaces is frequently applied to the evaporation of vat liquors. In this case, an iron pan termed the *salting pan*, in shape similar to the furnace above described, is placed at the end of the black-ash furnace next to the raised bed. The evaporation proceeds rapidly as with the ordinary white-ash furnace; but the mass of ash is not allowed to become completely dry. As soon as the contents of the pan have attained

the consistence of mortar, they are raked out into a large iron called the *drainer*, furnished with a false perforated bottom, to allow the mother liquor to drain from the crystals. The drained mass is next collected and introduced into a reverberatory furnace, named the *finishing furnace*, in which it is moderately calcined, and at the same time dexterously worked about in all directions so as to bring every part of it in contact with the air, and within the action of the flame. The mother liquor or draining from the *salts*, which contains nearly all the caustic soda and sulphide of sodium and iron, as well as the excess of foreign salts, sulphate of soda and chloride of sodium, *et cetera*, is in some works returned to the salting pans with the next charge of fresh liquor; in others it is evaporated *per se*, and the residue is afterwards heated to redness, mixed with saw-dust or coal-dust in reverberatory furnaces. During the process of calcination the sulphur of the sulphide of sodium escapes in some form of combination, and carbonate of soda is produced; the caustic soda also quickly combines with carbonic acid to produce the same salt, and the sulphate of soda is reduced at the same time to sulphide of sodium, and undergoes a similar change.

In manufactories where caustic soda is produced in a marketable form, it is principally extracted from the mother liquors above-mentioned.

The other method of conducting the evaporation of vat liquors is by means of iron pans, with the fire and heated air applied beneath. These—named *fishing pans*—are of considerable size, and shaped somewhat similar to a boat. They may be heated by a fire used solely for the purpose; in which case to prevent injury to the pan, the arch of the furnace should be continued for some distance beneath, or the pan may be placed at the end of the black-ash furnace farthest from the fire, just as with the salting pan, except that the heated air is made to pass under instead of over the pan. The evaporation is rapidly conducted by this method; and when the lie becomes concentrated to a certain strength, small crystals of monohydrated carbonate of soda— $\text{Na O, CO}_2, \text{H O}$ —constantly fall to the bottom, and as quickly as they fall are raked together to the end of the pan farthest from the source of heat, and then scooped or *fished* out by means of perforated iron shovels. After being allowed some time to drain, the salts so obtained are washed with fresh vat liquor, and then removed to a reverberatory furnace, and all worked about until sufficiently dry. The deep-red mother liquor is either applied to the production of caustic soda or evaporated, and the residue heated with sawdust as before directed.

In some alkali works the evaporation of black-ash liquors is conducted in a series of pans, three or four in number, or rather in one pan separated into three or four compartments; in the first, that is, the one at the greatest distance from the source of heat, the solutions are heated to the point of ebullition; in the next, or the two next, the liquors are concentrated until saturated while hot; and in that immediately in contact with the fire, the concentrated liquors are evaporated either to dryness, or until nearly the whole of the carbonate of soda is deposited from solution, and this is afterwards dried in a reverberatory furnace as before.

In the year 1853 an improved mode of concentrating black-ash liquors for the purpose of obtaining soda therefrom suitable for the manufacture of soda was invented by Mr. GOSSAGE, and secured by patent. The following description of the method is in the words of the patentee, and is extracted from the specification.—A long iron pan is provided and heated, either by means of a special fire underneath the same, or by waste heat proceeding from the alkali furnace. A second long pan is placed contiguous to the first, but in this no heat is to be applied; a channel of communication is provided, and having introduced a suitable quantity of black-ash liquor into both pans, heat is applied to the first pan, so as to produce concentration of the liquor. A continued circulation of the solution through the two pans is effected by pumping or otherwise transferring liquor from the second into the first pan, at the end opposite to that at which the channel of communication exists. By this arrangement the liquors become so concentrated in the first pan as to contain more salts when in a heated state than they can retain in solution at a lower temperature, and therefore as the liquors flowing through the second pan become reduced in temperature, salts are deposited in this pan, and the liquors circulate again through the first pan as required, so as to keep a suitable quantity in the apparatus.

In the process of concentration by the ordinary method in a single pan, the salts, as they are deposited from the solution, collect at the bottom, and form a compact mass of a greater or less thickness, and the heat being continued owing to the bad conducting power of the deposited salts, the part of the pan immediately over the fire, if constant attention is not exercised, frequently becomes heated almost to redness; and by any means the colder liquid comes in contact with this at so high a temperature, not only is the solution violently thrown from the pan, occasioning considerable loss of liquor, but often the latter becomes cracked and, of course, is rendered useless until repaired. The advantages of Mr. GOSSAGE's apparatus will therefore be at once apparent, since by his mode of arrangement none, or at least only a small deposition of salts, can take place in the pan to which heat is applied. The patent to which reference has just been made, also includes an improved mode of concentrating black-ash liquors, when it is desired to obtain therefrom in a remarkable state the caustic soda they contain. The apparatus employed consists of an oblong vertical tower, made of iron plates, to the inside of which tower is adapted a number of iron shelves, placed at such an inclination that fluid will flow freely down the same. One of these shelves is attached to one end and to both sides of the tower, leaving a space of about three inches in width between it and the other end. The next shelf is attached a few inches below the first to the opposite end and to the two sides of the tower, leaving the same space between it and the other end. In this manner each alternate shelf is attached to an opposite end of the tower, and the arrangement is such that a supply of fluid introduced on the upper part of the first inclined shelf flows down the same, and is delivered on the upper part of the second shelf, and after flowing over

this reaches a third, and so on consecutively over the whole number of shelves contained in the tower. By these means the fluid employed may be exposed, in thin sheets or films, to the evaporated action of heated air passing through the tower. A supply of heated air is provided by any of the ordinary methods, and the apparatus is connected with the previously mentioned tower, at or near its lower part; and to occasion a large quantity of heated air to pass through, the upper part of the tower is connected with a strong chimney draft. The liquid to be evaporated is introduced into the tower in such a manner that it becomes distributed nearly equally over the uppermost shelf, from which it flows in the same manner over the succeeding shelves, and, exposed to the evaporating action of highly heated air during its course, becomes so heated and concentrated as to contain more salts than it can retain in solution at a lower temperature. A channel of communication from the lower part of the tower is provided, through which the hot concentrated fluid is conveyed to two iron pans; in flowing through these it becomes cooled so as to deposit salts, and the remaining fluid is then elevated by means of a pump from the coolest part of the pans and caused to pass again through the tower.

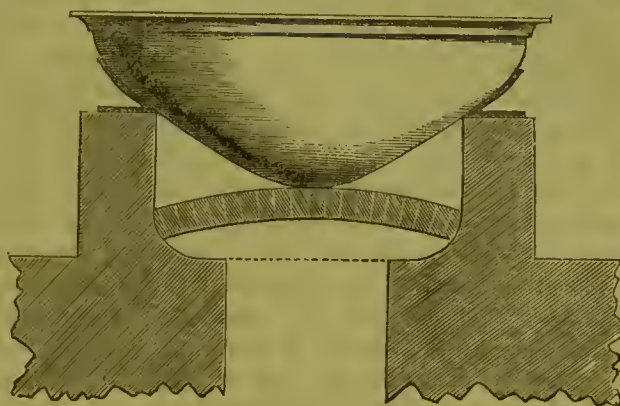
The inventor prefers to apply this mode of concentration for obtaining soda from vat liquors, to such liquors as have been already deprived of a considerable portion of the carbonate of soda previously contained therein. The circulation of these liquors through the tower is continued until it is found that the whole, or nearly the whole, of the carbonate of soda is removed, when the liquor is separated from the deposited salts, and by further evaporation in an iron pan solid hydrate of soda is obtained. The separated salts, after being washed, are transferred to a reverberatory furnace and completely dried. The product of these operations, whichever of the foregoing be adopted, is the *white ash* or *soda ash* of commerce. When properly prepared it contains fifty-three or fifty-four per cent. of available soda, two or three of which exist in the form of hydrate, and the rest as carbonate of soda. A little sulphide of sodium is also present, and some sulphate of soda, chloride of sodium, and minute quantities of other salts.

A new arrangement or apparatus for effecting the evaporation of black-ash liquors has been invented and successfully applied by Mr. D. GAMBLE, at St. Helens, Lancashire. It has been adopted very generally by the Lancashire manufacturers, particularly by those who are makers of solid caustic soda from black-ash liquors by GOSSAGE'S process. Mr. GAMBLE employs a pan of malleable iron, of the form indicated in Fig. 522, having a length of thirty feet, a width of seven feet, and greatest depth two and a half feet. The pan is placed above, or at the end of a black-ash furnace, and is heated by conducting the waste heat of the furnace by flues under the sides of the pan. The form of these sides is such as to afford facilities for separating the salts from the sides of the pan, when these adhere. During the boiling down, the salts are transferred in ladles into perforated drainers.

Mr. GAMBLE was also the first to use centrifugal machines, or hydro-extractors, for separating mother

liquors from salts obtained from black-ash liquors, and by such an apparatus soda ash of fine quality has been

Fig. 522.



obtained, by the first process, without being redissolved and evaporated.

The analyses of soda ash appended were performed by Mr. KYNASTON in the Editor's laboratory. The ash was obtained by evaporating the liquors at once to dryness, and calcining the residue.

	Centesimally represented.	
Carbonate of soda	67·891	73·626
Hydrate of soda	14·245	13·600
Sulphate of soda	4·579	6·127
Chloride of sodium	6·061	4·431
Sulphide of sodium	0·556	0·361
Aluminate of soda	1·214	..
Silicate of soda	0·389	0·511
Insoluble matters	0·217	1·579
Water	5·005	
Ultramarine	0·140	..
	100·297	100·235
Available soda	50·75	54·00

The soda ash prepared by the processes described is, without further treatment, sufficiently pure for almost all the ordinary manufacturing applications of soda. For some purposes, however, and especially for the fabrication of plate glass, or for the production of the crystallized carbonate of soda—soda crystals—the ash made as above requires to be still further purified; and this is most commonly effected by giving it another calcination in a reverberatory furnace, moderately heated, sometimes by a charcoal fire. Or the salts obtained by evaporation of the vat liquors, either in the reverberatory furnace, or in the *fishing pans*, after being thoroughly drained and washed as completely as possible from adhering impurities, either with fresh liquor or with water, are mixed with saw-dust or coal dust, and calcined in a reverberatory furnace.

This calcination is intended to effect the separation of the sulphur from the small proportion of sulphide of sodium still remaining in the ash, and also the combination of all the particles of caustic soda in the ash, with carbonic acid derived from the burning carbonaceous matters introduced.

The heat applied in the first part of this process should not greatly exceed the melting point of lead.

At that temperature the sulphur goes off freely; but at a dull red heat the sulphur, instead of being volatilized, seems to enter into more permanent combination with the alkali.

The ash requires to be worked about with the oar and rake during the whole course of the operation, which usually takes about three or four hours. After the sulphur is expelled as completely as possible, the fire should be gradually urged until the mass attains a dull red heat, and this is continued until every particle of carbon is removed. The product of this operation is usually of a slightly yellowish or bluish-white tinge, and is excellent material for the manufacture of plate glass. The available soda exists wholly in the state of carbonate, and if any, only the most minute trace of sulphide of sodium. It must not be supposed, however, that this result is arrived at without the most careful manipulation, and constant attention to keep the furnace at the proper temperature required in the several stages of the operation. Ash so prepared should not, on exposure to the air for some time, undergo any alteration in hue, and when dissolved in water should yield a perfectly colorless solution. If it answers to these tests, the plate glass manufacturer may rest assured of its applicability to his purpose.

This ash being wholly in the state of carbonate, the amount of available soda contained in it is not quite so great as in some other varieties.

CRYSTALLIZED CARBONATE OF SODA—Soda Crystals.—This salt is prepared by dissolving soda ash, obtained as above, in hot water to the point of saturation, and the solution after reposing for some time is run into shallow pans of cast-iron or of wood, lined with sheet-lead, and allowed to remain at rest until the crystallization is completed. That the operation may be successful in a pecuniary point of view, it is essential that the salt be obtained perfectly colorless by a single crystallization. It is, therefore, necessary to observe particular care in the several operations, and especially in the selection of the ash to be dissolved. Nor is it by any means unimportant that the water used should be as free as possible from carbonate of iron and the salts of the alkaline earths. The ash most suitable is that prepared by the method last described. The alkali contained in it must exist wholly as carbonate. Sulphide of sodium must not be present, even in the smallest proportion; it should be as free as possible from carbonate of lime, and on exposure to the air should not undergo the slightest alteration in color. The solution is effected in different ways by different manufacturers. In the mode now most commonly employed, the lie is heated by means of steam blown into it. The dissolving pan, which is of iron, should be of such a size that sufficient ash may be treated at one operation to yield two, three, or four tons of crystals. Water being run in to about two-thirds full, it is heated to nearly ebullition, and ash is then thrown in, the injection of steam being continued until the solution has a specific gravity of $1.225 = 45^\circ$ Twaddell. It is then siphoned into a capacious iron vessel termed the settler, where it is allowed to remain twelve or fourteen hours to deposit any insoluble matters that may be present. The clarified liquor is

now conducted to a boiler placed over an open fire, where it is heated and kept in a state of ebullition until the density becomes about $1.275 = 55^\circ$ Twaddell. At this point it is again run off to the settler, a pailful of solution of bleaching powder, or of chalk and water, or a mixture of these, is thrown in to aid the deposition of the impurities, and the whole is allowed to remain until the temperature is reduced to about 92° . At a little lower degree of heat crystals begin to be formed; but before this can take place the liquor is conveyed by means of sluices to the crystallizing pans or cones, which are of such a size as to contain sufficient liquor to give from a ton to a ton and a half of the crystallized salt. The annexed engraving shows the manner in which they are arranged in the crystallizing house.

To determine the formation of a larger quantity of very pure crystals, iron rods or bars are laid across the cones, and the crust that forms at the surface of the liquid, adhering to these, is prevented from falling, and will sustain also the mass of crystals that grow immediately beneath it. After nine or ten days—the length of time varying with the season—the crystallization may be considered complete. The mother liquor is then siphoned off, and by evaporation and calcination of the residue, a very white ash is obtained, containing about sixty-five per cent. of carbonate of soda, the other thirty-five being principally sulphate of soda and chloride of sodium. The crystals are allowed to remain a short time in the cones after the removal of the mother liquor, so as to drain and become dry, and are then taken out to be packed.

In some alkali works the soda ash, instead of being treated as above, is dissolved at once by the aid of steam, until the solution has attained a density of $1.275 = 55^\circ$ Twaddell. It is then drawn off to the settlers, a quantity of bleaching powder or chalk added, and when the temperature is near 92° , conveyed to the cones. From some varieties of ash, however, the impurities are not so readily separated, and it is necessary to substitute the process above given. The slimy deposit from the settlers with the adhering liquors, is either returned to the dissolving pan, or when collected in quantity is mixed with fresh water, boiled by means of steam; and the solution, after depositing the gross impurities, is added to the mother liquor from the crystals, and evaporated with it to dryness.

Though the process for the manufacture of soda ash, as detailed above, is very complete, and will probably never be superseded by any other method essentially different, still no one would think of asserting the impossibility of effecting any improvement. Many other modes of manufacture and several improvements of the old methods have been suggested, some of which deserve a brief notice.

A process invented by Mr. GOSSAGE, and for which he obtained a patent bearing date May, 1853, has for its object the purification of the black-ash liquors: firstly, by the oxidation of the sulphide of sodium, and, secondly, the separation of ferriocyanide of sodium from such liquors. During the ordinary process of evaporating black-ash liquors to dryness, and

roasting the product so obtained, the sulphide of iron and the iron of the ferrocyanide of sodium become converted into oxide of iron; and this substance communicates an objectionable color to the soda ash produced, rendering it unfit for certain applications.

The sulphide of iron being held in solution by sulphide of sodium, if the latter salt be converted by oxidation into hyposulphite— $\text{Na O, S}_2 \text{ O}_2$ —sulphite— Na O, SO_2 —or sulphate of soda— Na O, SO_3 —the sulphide of iron set free from combination becomes insoluble, and may be separated from the liquors by subsidence or filtration. In Mr. GOSSAGE'S process, as stated in the specification of his patent, the oxidation of the sulphide of sodium in black-ash liquors is effected by causing them to absorb atmospheric oxygen. To effect this as quickly as possible the liquors are made to pass through a high tower, termed by the inventor an *oxidising tower*, which is filled with small pieces of coke, or other suitable material; and while the liquors are percolating, a current of air is at the same time caused to pass through the interstices between the pieces of coke, by connecting the upper part of the tower with a chimney. By this arrangement an immense number of surfaces moistened with the liquors is presented to the current of air drawn through the tower, and the absorption of oxygen is thereby greatly facilitated. After passing through the tower, the liquors are collected in a pan to which heat is applied, and are afterwards pumped up, and caused to flow again through the tower. These operations are repeated until the sulphide of sodium in the liquors has become completely oxidised. The sulphide of iron, now in an insoluble form, is to be separated from the liquors either by subsidence or filtration; and the menstrua being rendered perfectly colorless, are freed from all iron except such as exists as ferrocyanide of sodium. When the black-ash liquors are to be used for the production of soda crystals, or of soda ash, the conversion of the caustic soda present into carbonate of soda, is, by a modification of the process, effected collaterally with the separation of the sulphide of iron. All that is necessary for this purpose is to cause carbonic acid gas to pass through the tower with the atmospheric air. The liquors so purified are to be concentrated by the usual method employed in the preparation of soda crystals, or so as to obtain salts therefrom. In the further treatment of these salts and the residual liquor, and also the salts obtained in a similar manner by evaporating the mother liquor from soda crystals, the second part of Mr. GOSSAGE'S purifying process, namely, the separation of ferrocyanide of sodium, comes into operation. The first portions of the salts so deposited are but little impregnated with ferrocyanide of sodium; the second portions contain more of this compound; and the last portions are strongly impregnated with ferrocyanide, whilst the mother liquors still remaining contain a large proportion of this salt in solution. To separate it from these salts, they are to be washed with water or a solution of carbonate of soda.

For this purpose a series of four vats is employed, and the process is conducted exactly as in the lixiviation of black ash. In this mode of washing, the salts contained in each vat successively become those

least impregnated with ferrocyanide, and are subjected to the first action of the water, or of the washing solution. The solutions obtained by such washings are mixed with the mother liquors of the salts; and if it be found by testing that the mixed liquors contain more than ten parts of carbonate of soda for each part of ferrocyanide of sodium present, they are to be concentrated so as to obtain a further quantity of salts therefrom; and this concentration and separation of salts is to be continued, as long as the proportion of ferrocyanide of sodium to the carbonate of soda is less than ten per cent. The salts obtained by this last concentration are to be introduced into the concentrating apparatus with fresh black-ash liquor. The liquors above referred to as containing ten per cent. less of carbonate of soda for each one part of ferrocyanide, are collected and mixed with sufficient water and caustic lime to convert the carbonate of soda present into caustic soda, and the solution so obtained is to be concentrated until the greater part of the ferrocyanide becomes separated as salt; or the separation of the ferrocyanide may be effected by allowing the concentrated solution to crystallize; or, instead of converting the carbonate of soda contained in the liquors into caustic soda, the solution may be impregnated with carbonic acid, when bicarbonate of soda, a compound of sparing solubility, will be formed, and the greater part of the ferrocyanide may be obtained by filtration of water through the same, and drainage. The solution of ferrocyanide now contains only a small proportion of soda, which is converted by means of lime into caustic soda, and from this the ferrocyanide is separated either as salts or by crystallization. By resolution in water and repeated crystallization, the ferrocyanide is obtained sufficiently pure to be suitable for use.

Mr. GOSSAGE'S patent further includes a process for the production of caustic soda in a marketable state, in addition to white soda ash and ferrocyanide of sodium from black-ash liquors. In this operation, also, the liquors are first submitted to the oxidising action of atmospheric air as already directed. Any hyposulphate of soda contained in the purified liquors is then converted into sulphite or sulphate of soda by further oxidation; and this is effected by the gradual addition of solution of chloroxide of calcium, or bleaching powder. The liquors are now concentrated by the ordinary method so as to obtain salts therefrom; and these are washed as before described, to separate all the caustic soda and ferrocyanide of sodium. The mixed mother liquors and washings are then again concentrated, until the whole or nearly the whole of the carbonate of soda and ferrocyanide of sodium have become deposited as salts, and the solution or mother liquor remaining contains scarcely any saline matter but caustic soda. In this state it is suitable for many purposes to which caustic soda is applicable, and is a marketable product. The mixture of carbonate of soda and ferrocyanide of sodium in the form of salts, is washed with water by filtration; and the residue and washings are further treated exactly as before directed, for the preparation therefrom of pure soda ash and of ferrocyanide of sodium. By further concentration of the solution of caustic soda in cast-iron pans, it may be

so far deprived of water as to become solid hydrate of soda when allowed to cool, and in this state it presents great facilities for transportation.

At a later date, namely in 1857, Mr. GOSSAGE patented another invention, the object of which is to obtain an increased proportionate quantity of caustic soda or caustic potassa, or of carbonate of soda or carbonate of potassa, in the usual manufacture of soda or potassa. In the case of soda, this is effected, firstly, by using an increased proportionate quantity of small coal in the mixture employed, when decomposing sulphate of soda by fluxing. The proportions of these usually employed are three parts of sulphate of soda, three parts of carbonate of lime, and one and a half or two parts of small coal; but Mr. GOSSAGE uses nearly equal weights of each of these materials, reserving some part of the small coal to be added as the decomposition proceeds. The decomposition of some part of the carbonate of soda produced is alleged to be effected in this way, and an increased proportionate quantity of caustic soda is obtained when the fluxed mass is lixiviated. It would appear, however, from what has been stated regarding the composition of black ash, that an increased ratio of the calcareous substance would be much more effectual.

The second part of the process consists in the addition to the solutions obtained, of hydrated oxide of iron, of zinc, of manganese, or of lead, whereby the sulphide of sodium present is converted into caustic soda, with simultaneous production of sulphide of the metal employed. The decomposition is effected by adding to the solution obtained by lixiviation at a boiling heat, such a quantity of the metallic oxide as is found, by testing the solution with a salt of lead, to be sufficient to remove the sulphur from the whole of the alkaline sulphide present. The metallic sulphide thus produced, after being washed with water, is decomposed by means of muriatic or some other suitable acid, and the metal is obtained in solution. This, decomposed by means of hydrate of lime or magnesia, yields the hydrated metallic oxide in a condition applicable to the decomposition of a further quantity of alkaline sulphide.

To obtain an increased proportionate quantity of carbonate of soda, instead of caustic soda, in the process of manufacture, the alkaline sulphide is to be decomposed by the addition of the carbonate of iron, zinc, magnesia, or lead, and the metallic sulphide produced is reconverted to the state of carbonate by the addition to the solution of the metal obtained, as before directed, of carbonate of lime or of magnesia. This process, it should be observed, is one of a series of improvements in the manufacture of soda patented by Mr. GOSSAGE at the same time.

The primary object of these improvements is to render again available in the manufacture the sulphur contained in alkaline waste, which in the ordinary method is totally lost. As these relate more especially to the economical production of sulphuric acid, they will be further noticed in connection with the article to be specially devoted to that substance.

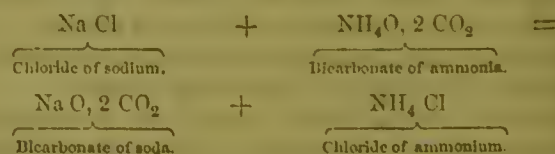
A process for impregnating black ash and white ash with carbonic acid, in order to convert the caustic and silicate of soda contained therein into carbonate, was

patented some years ago by Mr. JAMES SHANKS. In applying this process to black ash, the latter is broken into fragments and disposed in several layers, each of three or four inches in depth, in a stone or iron vessel named the *carbonator*. The layers having been moistened with water, carbonic acid gas is introduced into the carbonator by a pipe, the air being allowed to escape by another one. When the odor of a little hydrogen is strongly perceptible at the exit pipe, the whole of the soda is considered to be carbonated: the introduction of carbonic acid is then discontinued, and the black ash is removed to the vats and lixiviated in the ordinary manner. The lie prepared from black ash may be exposed to the action of carbonic acid in the case of the ash. In this case the carbonator used should have a capacity of sixteen cubic feet for every ton of white ash, or six cubic feet for every ton of soda crystal, to be made daily. Across the bottom of the carbonator is thrown an open arch of brickwork, and the space above is filled with small pebbles, over which the solution to be carbonated flows, being admitted at the top. The carbonic acid is introduced below the arch, and is allowed to rise in the carbonator between the pebbles, the air of the vessel escaping by a pipe at the top. The greenish-yellow or brown color of the liquor disappears when properly carbonated.

With the same object in view, Mr. JOHN WILSON obtained a patent in 1840 for a process in which the caustic soda contained in either black or white ash is converted into carbonate by the application of as much bicarbonate of soda as might be necessary.

The entire loss of all the sulphur consumed as sulphuric acid in LEBLANC'S method of converting common salt into carbonate of soda, is justly considered a great objection to that process. Still, although numerous suggestions have been made, none of the new processes have succeeded so well as to supersede LEBLANC'S method; and the Editor is of opinion that it never will be supplanted. At the same time some of the plans recommended are so interesting in a purely theoretical point of view, that the Editor would scarcely be justified in omitting all notice of them.

One of the most economical of these processes is that proposed by Messrs. HEMMING and DYER, which is founded on the behavior of a solution of common salt with one of bicarbonate of ammonia. When carbonate of ammonia of commerce, which is in reality a mixture of carbonate and bicarbonate, is added in a state of fine powder to a solution of about an equal weight of salt in three parts of water, the mixture being well stirred, a white crystalline precipitate appears in a few hours, causing the liquid to become thick. This precipitate is bicarbonate of soda, and there is contained in solution chloride of ammonium, produced as shown in the annexed equation:—

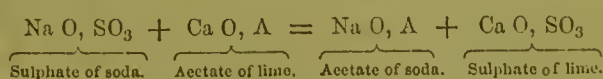


In the manufacturing process founded on this reaction, common salt is mixed with an impure carbonate

of ammonia, such as the liquor furnished by the purification of coal gas, or the distillation of bones; and, having separated the solid bicarbonate by pressure in a screw press, the chloride of ammonium remaining in the mother liquor is reconverted into bicarbonate of ammonia, by evaporating it to dryness, and treating the residue in a distillatory apparatus with carbonate of lime, as in the ordinary mode of preparing carbonate of ammonia. The advantage gained by this process is the production of soda without the use of sulphur, and therefore free from this element; the objection to it is the loss of ammonia, and also that the portion of chloride of ammonium necessarily remaining with the bicarbonate of soda, is in the heat *reconverted* into the cheap chloride of sodium. In referring to this method, PARNELL observes, that unless particular precautions be adopted, the loss of ammonia must be very great and inevitable, from two reasons:—First, when a mixture of chloride of ammonium and carbonate of lime is heated, a portion of the ammonia is always disengaged in the free state, the product not being a neutral carbonate, but a sesquicarbonate, having the formula $2\text{NH}_4\text{O}, 3\text{CO}_2$. In this process, therefore, one equivalent of ammonia in every three is disengaged in the free state and lost, unless particular means be adopted to retain it. Again, when the sesquicarbonate of ammonia is dissolved in water, it is resolved into the neutral carbonate and the bicarbonate; but chloride of sodium is decomposed by the bicarbonate only, and the neutral carbonate remaining in the mother liquor is decomposed during the evaporation into free ammonia and the bicarbonate, both of which are volatilized. The adoption of some patented improvements in the manufacture of carbonate of ammonia, in which the mixture of chloride of ammonium and carbonate of lime is impregnated with as much carbonic acid as it will absorb, whereby the sesquicarbonate of ammonia is wholly converted into bicarbonate, would also be a decided improvement on the preceding process of manufacture.

Other processes have been proposed for producing carbonate of soda directly or indirectly from common salt, and some of these were even known and practised before the discovery of LEBLANC's method. Thus, in 1788, a French priest named MALHUBE proposed a process which was afterwards put in operation by ALBAN, and was practised in France during the Revolution. In this, one hundred parts of sulphate of soda are first reduced to sulphide of sodium by heating to redness with twenty parts of charcoal; and while the mixture is in the liquid state, twenty parts of iron turnings are added, then eight parts of charcoal or small coal, next twelve and a half parts of iron, and lastly three parts of charcoal. The caustic soda thus obtained is exposed to the air, to absorb carbonic acid. DUMAS considers it probable, that in this operation there is formed a double sulphide of sodium and iron, and that the sodium converted into caustic soda is not more than half that contained in the fluxed product. In another process, sulphate of soda is reduced to sulphide of sodium by heating it to redness with charcoal, and having dissolved the sulphide in water, carbonic acid is passed through the solution till sulphide of hydrogen

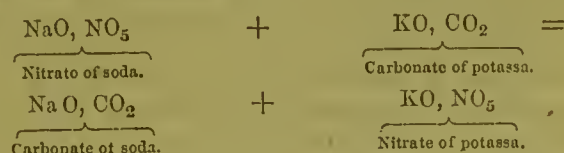
ceases to be evolved. The carbonic acid is produced by burning charcoal or coke, or by calcination of limestone. According to DUMAS, to decompose sulphide of sodium by carbonic acid it is indispensable to use a considerable excess of the latter, so as to produce the bicarbonate of soda. Mr. GOSSAGE, however, states that he has succeeded in effecting the decomposition with such a proportion of carbonic acid as to produce the ordinary monocarbonate of soda. MARGRAAF suggested that carbonate of soda might be produced from the sulphide, by first converting the latter into acetate of soda by means of pyroligneous acid. When this is heated to redness, a residue remains, consisting of carbonate of soda and charcoal. LAMPADIUS proposed to form the acetate of soda by the addition to a solution of sulphate of soda, of one of acetate of lime, when insoluble sulphate of lime and acetate of soda are formed:—



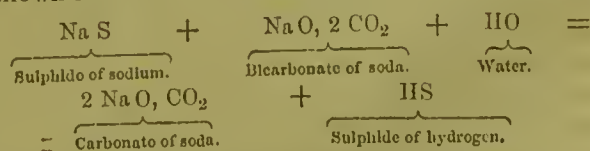
KÖBUNTER proposes to form carbonate of soda by decomposing sulphate of soda with carbonate of baryta:—



and KNAPP suggests that in districts where potassa is obtained at a moderate price, the production of saltpetre may be combined with that of soda, by decomposing Chili saltpetre—nitrate of soda—and carbonate of potassa into soda and ordinary saltpetre:—



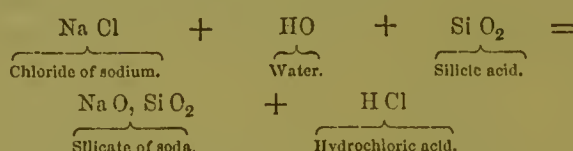
In treating of caustic soda, several methods for producing that salt, both from chloride of sodium and other salts of soda, have been detailed. These have also been applied in the manufacture of carbonate of soda, the caustic having been subsequently combined with carbonic acid, either by exposure to the air, or by heating it with coal or sawdust, or in some other way. In the patent of Mr. JOHN WILSON for improvements in the manufacture of carbonate of soda, already quoted, there is included a mode of preparing carbonate of soda from sulphide of sodium. He effects the conversion by mixing a solution of the sulphide with one of the bicarbonates, in the proportion of forty-eight parts of the former to eighty-five of the latter salt. The change is shown in the annexed formula:—



If the sulphide of hydrogen gas thus disengaged is to be collected, the materials may be mixed in a covered

iron pan, furnished with a pipe to conduct the gas to a gas-holder; but if the gas is not required the operation may be carried on in a common white-ash furnace. The mixture is evaporated to dryness, the residuary carbonate dissolved in water, and the clear solution is decanted and re-evaporated.

The soda process proposed and patented by MM. BLANC and BAZILLE, differs from nearly all the above-mentioned, inasmuch as the use of sulphur for the production of either sulphate of soda or sulphide of sodium is totally dispensed with. This method is founded on the decomposition of common salt by silica at a high temperature, and in the presence of steam. When the vapor of water is passed through an intimate mixture of common salt and silicious sand, contained in a porcelain tube heated to bright redness, the salt is decomposed, the chlorine unites with the hydrogen of the steam to form hydrochloric acid, which escapes as gas, while the sodium combines with the oxygen of the steam and with the silica or silicic acid, to form silicate of soda. The annexed equation represents the change:—



The decomposition, it will be observed, cannot take place unless water be present. In carrying out this process on a manufacturing scale, the patentees propose to introduce the mixture of salt and silicious sand into cast-iron cylinders, arranged in furnaces in a manner similar to gas retorts, so that the flame may play around and raise them to a cherry-red heat. A large perforated tube for the introduction of steam, as long as the cylinder, is to traverse the axis of each cylinder; and at one extremity of the cylinder the tubes must be each fitted to a large earthen or stone-ware tube for the purpose of conducting the evolved hydrochloric acid to the condensers. The latter tube should be of considerable size, to prevent its being choked up with volatilized salt; and it should lead first into a large empty chamber in which the volatilized salt might be deposited; a communication between this chamber and the condensers may afterwards be established.

The cylinders thus arranged are to be loosely filled with an intimate mixture of twenty-eight parts of salt and twenty parts of fine sand, and raised to a cherry-red heat; steam being at the same time slowly and steadily admitted into the perforated tube from a boiler.

To remove the undecomposed salt from the mass so obtained, it is to be lixiviated with water, in which the silicate is scarcely soluble; and to procure this in a state of solution, it is first calcined at a red heat with about one sixteenth of its weight of soda ash, until the mixture is vitrified. The subsilicate of soda thus formed is dissolved in water; and from the solution carbonate of soda may be obtained by impregnation with carbonic acid, which causes the precipitation of gelatinous silica; the soda salt remaining in solution. The patentees

prefer to procure the carbonic acid gas from the limestone by calcination in continuously acting limkilns. To the top of the kiln is adapted a dome-top, from which a tube passes into the vessel containing the solution to be carbonated; and it is alleged that the draught of the kiln is quite sufficient to maintain a proper degree of combustion to the end, if a single large vessel be employed to contain the solution instead of several small ones.

It is probable, as PARNELL remarks, that the manipulations required in these operations would be too tedious, and the decomposition of the salt in the cylinders too slow and incomplete, to allow of the process being prosecuted successfully on a large scale.

A plan was proposed by MAUGHAM for the production of silicate of soda, somewhat similar to the above, but with the additional aid of hydrofluoric acid. It then decomposes the silicate of soda by means of carbonate of lime.

SESQUICARBONATE OF SODA.—This salt exists as a natural product in solution in water. The mineral waters of Vichy and of Vals in France, of Bilin in Hungary, of Carlsbad in Bohemia, and the Geyser fountains in Iceland are remarkable examples. It is also produced as a mineral termed *trona* or *urn*, around the margin of some lakes in Northern Africa, Hungary, and South America. Its existence in nature is accounted for by some, on the supposition that chloride of sodium is decomposed by carbonate of lime, as BERTHOLLET observed that whenever these two salts were found mixed together there was also an efflorescence of sesquicarbonate of soda. DUMAS, however, dissents from this, and considers its formation to be owing to the decomposition of the sulphate of soda, which is always found in admixture with chloride of sodium. The sulphate of soda he supposes to be first reduced to sulphide of sodium by the action of organic matters in solution in the water; and the sulphide of sodium is afterwards converted into sesquicarbonate of soda by means of the carbonic acid also held in solution in the water of soda lakes. The lakes are usually called *white*, from the circumstance that, during the summer months, the water evaporating leaves a snow-white efflorescence on the surface at the bottom. This is sesquicarbonate of soda.

The plains on the shores of the Black and the Caspian Seas, Persia, Arabia, India, Thibet, China, and Siberia, and even the great desert of Africa—all furnish this variety of carbonate of soda.

This salt may be prepared artificially by several methods.

According to WINCKLER, if four ounces of alcohol be poured on the surface of a solution containing one hundred grains of simple carbonate of soda, and one hundred and fifty-two grains of crystallized bicarbonate of soda in four ounces of water; fine, clear, circular crystals of the sesquicarbonate are formed after several days at the surface of separation of the two liquids, and at the bottom of the solution large crystals of the simple carbonate are formed, together with a crust of bicarbonate of soda.

According to HUMANN, sesquicarbonate of soda

cannot be prepared pure by crystallization from any aqueous solution, as it decomposes when in solution into the bicarbonate and carbonate of soda, which crystallize apart. When a concentrated solution of the bicarbonate is evaporated quickly, so as to avoid the dissipation of the whole of the second equivalent of carbonic acid; when the bicarbonate and crystallized carbonate are mixed in single equivalent proportions, and the mixture is caused to undergo the watery fusion; and, lastly, when the bicarbonate of soda is exposed to heat, the temperature not being allowed to exceed 482° , products are obtained, which consist for the most part of sesquicarbonate. If these masses are exposed for a few weeks to a humid atmosphere, they assume a perfectly crystallized structure; and their cavities and fissures become lined with groups of crystals, which are pure sesquicarbonate of soda. The form of the crystal of this salt is that of the rhombohedral prism, terminated by quadraugular pyramids. It dissolves in water more readily than the bicarbonate, but less easily than the simple salt, and the solution possesses an alkaline reaction. It is unalterable in the air, a remarkable proof of which is given by DUMAS, who asserts that the walls of Cassar, a fort in Africa actually in ruins, have been constructed with natural masses of this salt, originally obtained from some of the native lakes which abound in the country. It was formerly imported into this country, and sold under the name of *tronse*, and hence probably originated the error of the London college in substituting the sesquicarbonate for the bicarbonate of soda.

BICARBONATE OF SODA.—This salt may be obtained by passing carbonic acid through a concentrated solution of the simple carbonate; but the process is tedious and attended with much waste of gas, unless pressure be employed. Some manufacturers economize carbonic acid, by exposing the solution for a long period in shallow vessels to the atmosphere of a fermenting vat. In both cases bicarbonate of soda separates after some time in minute grains, owing to its comparatively sparing solubility; and the mother liquor, by cautious concentration at a temperature not exceeding 120° , yields a further quantity. In the process of SCHÖFFER, from three to four parts of crystallized carbonate are intimately mixed with one part of commercial sesquicarbonate of ammonia; the semifluid mass thus obtained, which evolves ammonia, is allowed to stand twenty-four hours, and then exposed to the sun on a clear surface. The last trace of ammonia escapes with the water, and bicarbonate of soda remains as a chalky mass. As the ammonia evolved in this method is lost, and as it is difficult to evolve in close vessels, SCHÖRZ proposed to mix fifty parts of dry carbonate of soda in fine powder with fifteen parts of the crystallized carbonate and forty-one parts of carbonate of ammonia, and to heat the mixture in a distilling vessel immersed in water.

The first nine-twelfths of the ammonia are readily evolved; the second two-twelfths with greater difficulty; and the last one-twelfth is removed by exposing the mass to the air. Manufacturers on the large scale have generally abandoned all the liquid processes for producing bicarbonate of soda, in favor of the dry

way; and this is certainly preferable both as regards economy, convenience, and despatch.

The process commonly followed is that suggested by SCHÖFFER, and introduced into the Parisian codex of 1840. It consists in packing fragments of crystallized carbonate of soda upon a series of perforated shelves in a box, or in large air-tight iron cisterns without shelves, but with an airhole at the side, and a small pipe at the bottom to carry off the water of crystallization, which separates during the process. After the introduction of the salt, carbonic acid is admitted in a stream regulated according to the rate of its absorption. The carbonic acid may be derived by the decomposition of chalk or limestone by hydrochloric acid, or, with proper precautions, from a charcoal or coke fire, or from a liquor undergoing the vinous fermentation. The latter method may be advantageously practised in distilleries, where a great quantity of liquor is kept in a fermenting state for a considerable time.

As carried on in alkali works, the first method is the one usually practised; the muriatic acid obtained in the production of sulphate of soda being made to act upon chalk or limestone.

The evolution apparatus employed consists of a large stone cistern laid in clay and well bedded. It is provided with a pipe, continued to within a few inches of the bottom of the cistern, and through this the acid is admitted from the condensers. The cistern being filled with chalk, the acid is allowed to flow in, and, rising through the mineral, it disengages carbonic acid in the passage; and the solution of chloride of calcium formed escapes through another pipe, similar to that by which the acid is admitted. The escaping liquors flow off through a third pipe, and the carbonic acid issues through an opening, whence it is conducted to the cisterns or boxes containing the crystallized carbonate of soda. The gas coming in contact with the crystals is very rapidly absorbed; and at the same time a liquid, charged with carbonate of soda or sesquicarbonate, trickles down to the bottom of the cistern, owing to the carbonate containing more water of crystallization than is required to constitute the bicarbonate. This liquid is usually withdrawn from time to time, as may be necessary. During the absorption of the gas a considerable amount of heat is evolved; and at the end of ten days or a fortnight the whole is converted into bicarbonate of soda, which is, however, very damp. This moisture is removed by heating the mass in stoves fitted with wooden shelving, by air passed through hot iron pipes.

A great improvement on this method in small operations, and which has also been adopted on the large scale, is the process suggested in its details by MOIR. In this method, the crystallized and anhydrous carbonates are mixed in such proportions as to leave a slight excess of water over what is necessary for the water of crystallization of the whole salt, when it is converted entirely into bicarbonate; and carbonic acid is admitted to the bottom of the mixture by a tube proceeding from a pneumatic apparatus similar to a gasometer, so constructed that there can never be any waste of gas. The absorption is completed every twenty-four hours.

MOHR proposed to mix anhydrous carbonate so as to leave no excess of water over that required for the water of crystallization of the bicarbonate. CHRISTISON, however, who carefully investigated the subject, found that absorption does not take place at all with the proportions proposed by MOHR; that with nothing but crystallized carbonate the absorption is slow, and the disengaged water contains carbonate or sesquicarbonate; but that with such proportions of the crystallized and anhydrous carbonates as will leave a slight excess of water, absorption is prompt, a slightly damp salt results, and there is not an appreciable quantity present of any other carbonate besides the bicarbonate.

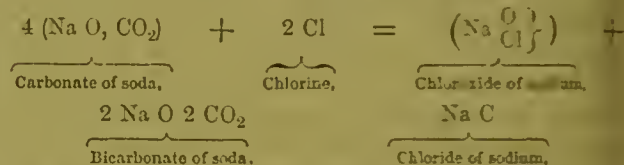
The rapidity with which effloresced carbonate of soda, or what is practically the same, a mixture of crystallized and anhydrous carbonate, absorbs carbonic acid, is stated by ARTUS to be considerably increased by mixing with the salt recently calcined and powdered charcoal, made from soft wood, which possesses the power of condensing gases within its pores to an extraordinary extent. When it is desired to obtain the bicarbonate in crystals, advantage may be taken of this property of charcoal. The mixture, which may be made in the proportion of two parts of effloresced carbonate and one part of charcoal, is moistened and exposed to the gas for twenty-four hours, then taken out, powdered, and moistened, and again exposed to the gas. These operations having been twice repeated, the mass is mixed with eight parts of hot water; the solution is filtered while hot, and left for the bicarbonate to crystallize. Carbonate of soda is known to be fully saturated with carbonic acid when it no longer reddens turmeric, or gives a precipitate with a very dilute solution of chloride of mercury or corrosive sublimate, but with a concentrated solution a white precipitate, which becomes red in a few minutes, and afterwards purple; with the least admixture of simple carbonate of sesquicarbonate of soda, the precipitate is reddish-brown.

Bicarbonate of soda is known only in combination with water, its formula being— $\text{Na O}, 2 \text{ CO}_2, \text{HO}$. It crystallizes in oblique four-sided tables, which have a slightly alkaline taste and a very feeble alkaline reaction on vegetal colors. As met with in commerce, it is usually in the form of powder, or in small, white, opaque, irregular scales. At a moderate heat, it loses half its carbonic acid and the whole of its water, and is reduced to the state of anhydrous monocarbonate. Cold water dissolves about one-tenth of its weight, and hot water considerably more. When the solution is heated somewhat above 120° , carbonic acid begins to be eliminated; and, according to BERZELIUS, at 212° the salt becomes sesquicarbonate.

Physiological Effects.—Bicarbonate of soda possesses diuretic properties, but less actively than the corresponding salt of potassa. It is also an excellent antacid and antilithic, and is employed in great quantity for making effervescing powders. A mixture of this salt with the tartrate of soda and potassa, or Rochelle salt, with the addition of tartaric acid, constitute sedlitz powders. Many have thought that the long-continued use of alkaline carbonates in gravel and acidity of the stomach entails injurious consequences; and diseases of the kidneys as well as organic disorders of the

stomach have been referred to the practice. The suppositions are probably imaginary, as there can be no question that many have employed alkaline remedies habitually for years, without apparently any deleterious effects being produced; the Editor can affirm this from his own experience.

HYPOCHLORITE OF SODA—CHLORIDE OF SODA—CHLOROXIDE OF SODIUM.—A solution of this salt in an impure state constitutes the well-known disinfecting liquor of LABARRAQUE. Its disinfecting power was discovered about the year 1820. The process for preparing this solution given in the London Pharmacopoeia is as follows:—A pound of crystallized carbonate of soda is dissolved in two parts of water, and the chlorine eliminated by heating a mixture of four ounces of common salt, three ounces of binoxide of manganese, four of sulphuric acid, and three of water, is conducted into the solution. The changes that ensue are represented in the subjoined formula, the result of the decomposition being a mixture of bicarbonate of soda, hypochlorite of soda, and chloride of sodium:—



The above is the method followed in the preparation of this salt by LABARRAQUE; PAYEN proposed another, which was adopted by the French pharmacists. It consists in the decomposition of chloroxide of calcium, or bleaching powder, by carbonate of soda. The proportions employed are one part of bleaching powder and thirty of water, and for the carbonate of soda solution two parts of the crystallized carbonate and fifteen of water. In this process hypochlorite of soda and chloride of sodium are formed, and remain in solution whilst carbonate of lime is precipitated. By using the proportion of the French Codex, the solution obtained is much weaker than that prepared as directed by the London College. Pure hypochlorite of soda can only be obtained by neutralizing a solution of hypochlorous acid with one of soda.

LABARRAQUE's disinfecting compound may be obtained in the solid state, according to MAYER and SCHINDLER, by transmitting chlorine, evolved from ten parts of common salt, eight parts of binoxide of manganese, and fourteen parts of sulphuric acid, into nineteen parts of dry powdered carbonate of soda, moistened with one part of water only. The absorption of chlorine goes on slowly with the disengagement of heat.

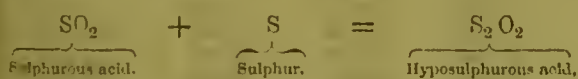
Properties.—The solution known as LABARRAQUE's disinfecting fluid is colorless or slightly yellow, has an odor of chlorine and an astringent taste. Upon vegetal coloring matter it first reacts as an alkali, and afterwards effects its destruction. By evaporation needle-shaped crystals are obtained, which when redissolved in water reproduce the bleaching fluid. Acids added to the solution disengage chlorine and carbonic acid gas, and by exposure to the air decomposition is also effected, and crystals of carbonate of soda are formed.

Physiological Effects.—This salt, as well as the soluble hypochlorites, is supposed to exercise a specific

influence over the nervous system, causing depression and tetanus. In small doses it has been considered to possess tonic, alterative, and febrifuge properties, and has, consequently, been proposed as a remedy in strumous diseases, chronic affections of the liver, ague, and the typhoid form of continued fever. Its utility as an external remedy is, however, much better established than its alleged therapeutic properties as an internal agent. When considerably diluted it is an excellent stimulant for ill-conditioned sores on the surface of the body, and especially for promoting cicatrization.—*Christison*.

According to PEREIRA it is most valuable as a disinfectant antiseptic, and as an antidote in cases of poisoning by the sulphides and by hydrocyanic acid; and he remarks, that in several cases where he had carefully compared it with chloroxide of calcium he gave the decided preference to the chloroxide of sodium. LABARRAQUE recommends its employment as an antiseptic, on the ground that by the process of disinfection it becomes chloride of sodium, which is not a deliquescent salt, whereas the chloride of calcium existing in and generated by bleaching powder, attracts water from the atmosphere, and thereby furnishes one of the conditions necessary to the putrefactive process. Hence, in his opinion, while chloride of lime will serve equally well for mere disinfection, chloride of soda is preferable when one wishes at the same time to prevent a renewal of putrefaction.

HYPOSULPHITE OF SODA.—There are several modes of procuring this salt. It is very conveniently prepared by first forming a solution of neutral sulphite of soda, by passing sulphurous acid gas into a strong solution of the carbonate of this base. The sulphite so obtained is then digested with sulphuric acid for several days at a moderate heat. In this case sulphurous acid, by taking up sulphur, becomes hyposulphurous acid, thus—



Or a solution of soda may be first saturated with sulphur by boiling, and sulphurous acid may then be passed through this menstruum, when hyposulphite of soda is formed. In either case the solution obtained is rapidly evaporated to a sirupy consistence and then set to repose, when the hyposulphite separates in large colorless crystals.

A very convenient process for the production of this salt on the small scale is that recommended by WALCHNER. A pound of pure crystallized carbonate of soda is dried as perfectly as possible, and then intimately mixed with five ounces of pure sulphur; the mixture is gradually heated in a glass or porcelain basin to the melting point of the sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part in contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water boiled with sulphur for some time, and the filtrate is evaporated, when very fine and pure crystals separate. If the heat employed be too strong, part of

the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is necessary.

Properties.—Crystallized hyposulphite of soda— $\text{Na O, S}_2\text{O}_2, 5\text{H}_2\text{O}$ —is an inodorous salt with a taste first cooling, and afterwards bitter. The crystals are oblique prisms, belonging to the right prismatic system. They are deliquescent in the air, but *in vacuo* lose their water of crystallization. When heated, the salt at first undergoes the aqueous fusion, and then dries up into a white mass; the heat being continued, it takes fire, burning vividly and with a clear yellow flame. Hyposulphite of soda is readily soluble in water, but not in alcohol. In close vessels the aqueous solution deposits sulphur till nothing but sulphite of soda remains in the liquid; exposed to the air it deposits sulphur, and the sulphite is converted into sulphate of soda.

Hyposulphite of soda, and other soluble salts of hyposulphurous acid, possess the remarkable property of dissolving all the compounds of silver, even the chloride, and the solution thus formed has a very intense sweet taste, with a metallic after-taste. This property has been made available in the daguerreotype, for the purpose of dissolving the sensitive coating of iodide from the plate of silver after exposure to light, and thus fixing the image already formed. For this purpose hyposulphite of soda is now prepared on a very considerable scale.

ANALYSIS.—The compounds of sodium may be distinguished from all other salts in a most unmistakable manner, though the tests are almost of a purely negative character. In the pure state, the mode of recognition is as follows:—When dissolved in water, no precipitate or other change is produced by the addition of hydrochloric acid, sulphide of hydrogen, sulphide of ammonium, carbonate of ammonia, or bichloride of platinum; but if the solution be evaporated to dryness, or if a little of the original substance be taken and exposed on a platinum wire to the inner flame of the blowpipe, the outer flame becomes of an intense yellow color, owing to the reduction of the soda and the subsequent oxidation of the reduced sodium.

This test is a safe, and mostly in itself sufficient proof of the presence of soda, provided always a fixed alkali alone be present and in the form of chlorides; the one hundredth part of soda may by this means be detected in presence of potassa. A precipitant has been proposed for soda, which is not, however, of any great value, and is very rarely employed; this is the antimoniate of potassa. It produces, in neutral or alkaline solutions of salts of soda, a white crystalline precipitate of antimoniate of soda, which in concentrated solutions is formed immediately, but in dilute solutions, only after the lapse of some time. Its formation is promoted by vigorous shaking of the mixture. This test gives decisive results only when applied with a careful and attentive consideration of the attendant circumstances. The most indispensable condition of its applicability is, that besides soda and potassa, no other bases must be present in the solution, since the salts of the heavy metallic oxides, those of the earths proper, and of the alkaline earths, and finally those of ammonia, are also

thrown down by antimoniate of potassa. The solutions, too, must be neutral or alkaline, since otherwise the reagent suffers decomposition, and hydrated antimonie acid or acid antimoniate of potassa is precipitated from it. Soda is usually estimated quantitatively as sulphate of soda or as chloride of sodium.

Other compounds of soda are converted into sulphate by adding to their aqueous solution a quantity of sulphuric acid more than sufficient to saturate the whole of the soda; the solution is then evaporated to dryness, and the excess of sulphuric acid expelled by ignition, adding now and then a portion of carbonate of ammonia.

Every one hundred parts of sulphate of soda so obtained represent 43.66 of soda. Of chloride of sodium obtained in a similar manner, one hundred parts represent 39.34 of sodium, or 53.02 of soda. Salts of soda are also sometimes determined as carbonate of soda; and for soda salts with organic acids this method is preferable to all others.

Caustic soda is converted into carbonate by adding to its aqueous solution carbonate of ammonia in excess, evaporating at a gentle heat, and igniting the residue. The bicarbonate of soda is converted into the simple carbonate by ignition; and the salts of soda with organic acids are converted into the carbonate by heating gradually in a covered crucible, the charcoal being afterwards removed by igniting the residue in a gentle current of air. Every one hundred parts of carbonate of soda obtained represent 58.49 of soda.

Lastly, the determination of the commercial value of

some soda compounds, as soda ash, caustic soda, *berz.*, *et cetera*, is effected by noticing the quantity of acid of known strength required to neutralize a given weight of the salt. The process recommended by Mr. FARADAY is as follows:—Into a tube of about three-quarters of an inch in diameter, and nine and a half long, and as cylindrical as possible throughout its whole length, one thousand grains of water are to be weighed, and the space occupied marked on the tube with a fine line; this space is then divided from above downwards into one hundred equal parts. At 23.44 or 76.56 parts from the bottom an extra line should be made, and soda marked opposite to it; at 48.96 potassa should be marked in the same way; at 54.63 carbonate of soda; at 65 carbonate of potassa. A diluted acid is now to be prepared, which shall have a specific gravity 1.127, and this is made by mixing intimately together ninety parts by weight of oil of vitriol and eighty-one of water. The method to be followed in the employment of this acid is as follows:—The dilute acid is to be measured in the tube up to the line opposite to which the alkali sought for is marked; if barilla, which contains carbonate of soda, 54.63 measures are to be taken. The one hundred measures are then made up by the addition of water, and is then ready for use. But these processes, which constitute a very important branch of commercial analysis, have been fully discussed under *Alkalimetry* in connection with the article POTASSA. Vol. II., page 729 *et seq.*, to which the reader is referred for details.

STATISTICAL REPORTS OF THE ALKALI TRADE OF THE UNITED KINGDOM FOR THE YEAR 1852, DRAWN UP BY
J. WILLIAMSON, ESQ., JARROW CHEMICAL COMPANY, SOUTH SHIELDS,

From full returns by sixteen manufacturers, representing 46% of the trade.
From partial returns by eleven manufacturers, representing 35% " "
No returns by sundry manufacturers, representing 19% " "

RAW MATERIAL CONSUMED, IN TONS.

	Newcastle- on-Tyne.	Lancashire	Glasgow and the Clyde.	Wales, Ireland, and South of England.	Midland.	Total.
Sulphur,.....	7,580	none	3,000	none	940	11,520
Pyrites,.....	33,750	40,220	9,000	12,000	5,292	100,262
Salt,.....	57,905	40,152	19,120	12,000	8,370	137,547
Coals,.....	232,020	136,400	80,000	36,500	34,500	519,420

QUANTITY OF PRODUCE, IN TONS.

Alkali,.....	23,100	26,343	12,000	7,000	2,750	71,493
Crystal soda,.....	42,794	3,500	6,000	3,500	5,250	61,044
Bicarbonate of soda,.....	4,046	1,200	none	none	516	5,762
Bleaching powder,.....	5,000	1,250	5,000	1,850	none	13,100
Number of men employed,.....	3,067	1,519	900	470	370	6,326
Amount expended in apparatus,.....	£344,000	172,000	100,000	50,000	36,000	702,000
Amount annually expended in repairing the same,.....	£69,500	23,000	20,000	11,000	6,200	129,700
Tonnage of shipping employed,.....	189,100	71,200	70,000	35,000	8,000	373,300

71,193 tons alkali, at £10,.....	£711,930
61,044 " crystal soda, at £5,.....	305,220
5,762 " bicarbonate of soda, at £15,.....	86,430
13,100 " bleaching powder, at £10,.....	131,000

Total value of products.....£1,234,580

VALUE OF MATERIALS IMPORTED FROM OTHER COUNTRIES.

11,520 tons sulphur, at £6,.....	£69,120
4,800 " nitrate of silver, at £15,.....	72,000
12,000 " manganese, at £2 10s.,.....	30,000

£171,120

Amount contributed by the alkali trade to the annual income of this country,.....£1,063,460.

This report is the only accurate return ever made of the alkali trade. The manufacture in Lancashire has, however, greatly increased of late years; but if the total amount given be doubled, the figures will represent pretty nearly the present yield of the manufacture.

STARCH.—*Amidon*, French; *Sterke*, German; *Amylum*, Latin.—Starch exhibits to the naked eye the appearance of a white glistening powder, which, under a higher visual power, is found to be composed of a number of very minute, colorless, and semitransparent grains. It is a secretion educed from most plants and seeds, though contained in some in much greater proportion than in others; and it would appear that its end is to produce cellular structure under the vital power of the plant, as well as to give support to the embryo seed till it is able to gather sustenance from extraneous sources.

HISTORY AND SOURCES.—This substance has long been known: the ancient Greeks called it *αμυλον*, from the circumstance of its not being prepared by grinding in mills like other farinaceous matters. PLINY attributes to the inhabitants of the island of Chio the discovery of the method of extracting it from wheat flour. Very little is said concerning it in any historical work down to modern times. FOSBROKE states that starches of various colors were imported into England from Holland in 1564—that which was yellow being esteemed the best for ruffs and other articles.

The starches more commonly known as products of particular seeds or parts of plants, are in a measure restricted to a definite number of organic productions, which secrete them for the purposes already alluded to; but if by starch be meant the analogues of this substance, having the same or a closely allied composition, then it may be said to form a constituent of all plants at one stage or another of their existence. The fact that starch of one form or other enters at some particular period into the composition of plants, is the more certain from the consideration of the variety of starches and their congeners. Of these there are three kinds known, namely, *common starch*—such as is extracted from the monocotyledonous and bicotyledonous seeds, and from several roots, tubers, *et cetera*—also *lichen starch*, and *inulin*. The first is the primary link between cellulose and dextrin or artificial gum; the second is intermediate between cellulose and dextrin; and inulin is the connecting link between common starch and sugar. On examining the transformations which the seeds of many plants, such as the cereals, the tubers, or leguminous plants—seeds which are rich in starch—undergo when germinating, it is evident that they effect the solution of the substance of the amylaceous matter into gum, or dextrin, or sugar, whence the carbon necessary for the increase of the young germ is extracted; and so likewise the starch which is abundant at one period of the growth of plants, but which at a more advanced stage disappears, must have passed through an analogous modification necessary for the development of another secretion. This department of vegetal physiology is, however, not sufficiently investigated to admit of explaining with certainty the intermediate stages of the secretion and decomposition of the starch granules in plants; but the fact that starch appears at one period of the growth of a plant or the formation of a fruit, and disappears at another, warrants the supposition that where sugar or gum is discovered, starch, organized in the form of granules or in some other

stages, has probably preceded these, or will result from them.

The term starch may be used here in a generic sense to designate the variety of organized structures educed from seeds, roots, and stems of plants belonging to different orders and families, in consequence of such educts offering marked analogies of properties and composition, though differing in physical characters. When it is requisite to distinguish the particular kinds, the source is mentioned; hence wheat, potato, arrow-root, sago, rice, and other starches. Wheat starch is generally called *amidon*, which term is applied not only to the amylaceous matter educed from wheat, but likewise to the similar products of the other seeds of the cerealia in the grains of the leguminosæ, the chenopodiaceæ, *et cetera*. Potato starch has its synonym in *fecula*, and this also is the term by which the starch from the carrot, beet, yam, and the like, are distinguished from the foregoing, as likewise arrow-root, sago, and other kinds. Arrow-root starch is found in the roots of many plants belonging to the family of *Scitamineæ zingiberaceæ* and *euphorbiaceæ*, as the *maranta arundinacea*, and *indica*, from which it is extracted in Jamaica; and the *curcuma angustifolia* from which it is prepared in the East Indies. Sago starch exists in the pith of the palm tribe, especially the *Sagus Rumphii*, *Cicasinermis*, *C. revoluta*, *Corytha urens*, *Borassus gomato*, and several species of *Zamia*, *Corypha*, and *Mauritia*, and can be extracted from them. Besides these, there is another variety of amylaceous secretion, which, differing from them in physical characteristics, is still allied to the preceding in chemical composition, and this is known as *inulin*. It is the immediate principle extracted from the roots of many plants, as the *dahlia*, *elecampene*, *inule*, *helenium*, *colchicum*, *dandelion*, *chicory*, *Iceland moss*, *Carrageen moss*, and several of the lichen and fucus tribe of plants. The latter is little used in the industrial arts of Europeans, though employed in China for the manufacture of transparent lamps and tablets similar to the gelatin articles of the French.

PHYSICAL PROPERTIES.—Particles of starch viewed under a high magnifying power, appear in well-defined grains, in most cases more or less oval; in others polygonal. Notwithstanding an evident analogy between starch particles, from whatever sources obtained, there still remains such difference in their shape and size as to enable any person acquainted with them to identify any particular species even when mixed with others from a different source. Size is the most important criterion, and PAYEN's researches in measuring the relative magnitude of the starch granules from various sources, constitute perhaps the best guide for the student; hence the following measurements and engravings of the appearance of the various starches, from his *Chimie Industrielle*, will be found useful. The details are of forty-one varieties:—

Fig. 523.—*Fecula* of the *Canna gigantea* measure in length 175 thousandths of a millimetre—equal seven thousandths of an inch, the millimetre being 0.03937 of an inch; *a*, *b*, *c*, *d*, *e*, represent the normal starch granules; *f*, *f'*, *f''*, granules partly exfoliated by vegetation which wastes them. The grains of the

Columba roots—*Minispermum palmatum*—measure 180 thousandths of a millimetre, and those of the

Fig. 523.



Case 1.

large ripe potato—of Rohan—185 thousandths of a millimetre.

Case 2.—Fecula of the arrowroot of commerce—*Maranta arundinacea*—attains a length of 140 thou-

Fig. 524.



Case 2.

sandths of a millimetre; *a, b, c, d*, represent the normal external coating separated from the inclosed matter by pressure. Fecula from the bulb of the lily has the same dimensions.

Fig. 525.



Case 3.

Case 3.—Bean starch, the maximum length of which is 75 thousandths of a millimetre—three thou-

sandths of an inch. At *a a', b b', c c', d d'*, the granules are seen in two positions, exhibiting length, breadth, and depth, and also the median canalled impression.

Case 4.—Starch from the tubercles of the *Oca crenata*, 85 thousandths to 100 thousandths of a millimetre. Fecula from the largest *Echinocactus* *crinitus* imported, 75 thousandths of a millimetre.

Cases 5 and 6.—Detached and agglomerated grains of the pith of the *Cycas circinalis*—sago—the largest

Fig. 526.



Case 4.

Case 5.

Case 6.

of the largest of which measures 50 thousandths of a millimetre.

Case 7.—Wheat starch granules, *a, a', a''*, in three positions, the largest of which are from 45 to 50 thousandths of a millimetre.

Case 8.—The same starch, the orifice or hilum

Fig. 527.



Case 8.

Case 7.

which is rendered visible by heating to 396°, and examining the granules subsequently in alcohol of 0.85 specific gravity.

Case 9.—The same starch viewed after the evaporation of the alcohol, showing where the residual water has dissolved a portion of the exterior of the globule.

Fig. 528.



Case 9.

Case 10.

Case 10.—The same starch after the internal matter has been dissolved by an excess of water.

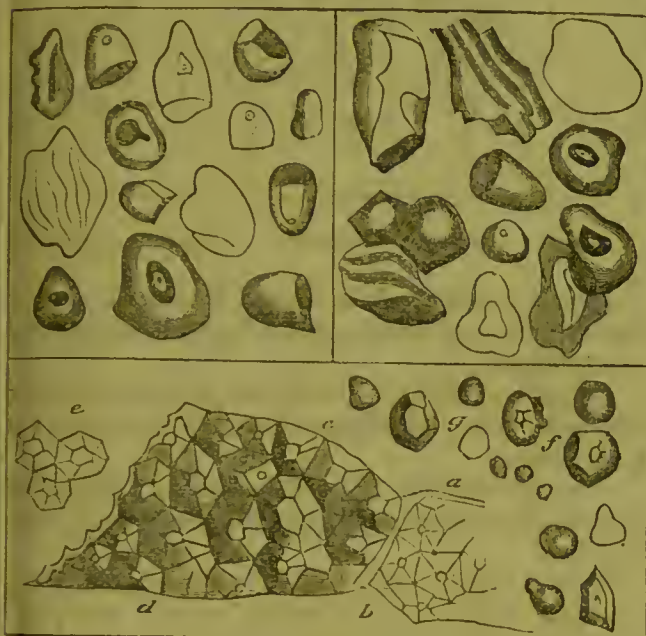
Case 11.—Fecula of the red sago of commerce, the grains of which are partly swollen and deformed by heat.

Case 12.—Fecula of white sago, showing the alterations suffered in the preparation by the effects of a high temperature and the presence of a large quantity of water; this variety, as also lentil starch, measures 75

Case 11.

Fig. 529.

Case 12.



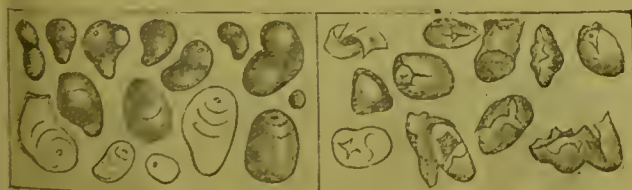
Case 13.

thousandths of a millimetre; kidneybean or haricot starch 67 thousandths; and that of large peas 36 thousandths of a millimetre.

Case 13.—Indian corn starch. Here *ab, ed*, represent the grains encased and compressed in two contiguous cells of the horny part of the perisperm; *e, e, e* represent three compressed grains; *f, g*, detached grains, 25 to 30 thousandths of a millimetre.

Case 14.—Fecula of the bulb of the hyacinth, showing several double grains; the greatest length is 45 thousandths of a millimetre.

Fig. 530.



Case 11

Case 15.

Case 15.—The same, showing the exfoliation of the granules in an old shell.

Case 16.—Fecula of beet, showing several double grains and appearing conical; length 40 thousandths of a millimetre.

Case 17.—Shows the same heated to 360° to develop more plainly the hilum or aperture.

Case 18.—The same fecula as it appears at the commencement of its hydration after the evaporation of the alcohol.

Case 19.—Fecula of the *Orchis bifolia*, many granules of which have two apertures or hila, and double lateral conical protuberances.

Case 20.—Fecula of the *Orchis latifolia*, the grains of which are ovoidal, pear-shaped, *et cetera*, with a

Case 16.

Fig. 531.

Case 18.



Case 17.

Case 19.

double hilum. Both these kinds of starches measure 45 thousandths of a millimetre.

Case 21.—Starch grains found in the tubercle of the potato, the growth of which was arrested. The granules are seen forming two or more smaller corpuscles at the expense of the larger ones; also the more developed

Fig. 532.



Case 20.

Case 21.

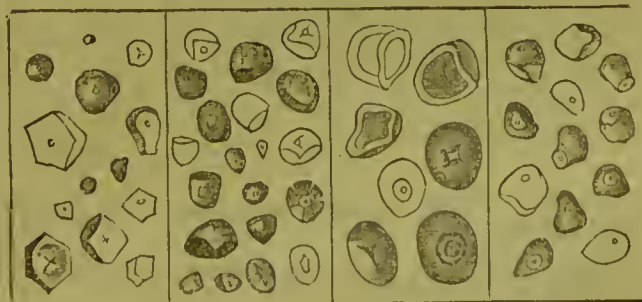
Case 22.

grains, several of which are adhering two and two together, with a few grains acted upon with a solution of soda containing 0.005 of the caustic alkali, and swelling the matter in the interior so as to cause it to exude.

Case 22.—Fecula extracted from the stem of the *Cactus Peruvianus*, showing the single, double, and triple grains. It measures from 25 to 30 thousandths of a millimetre.

Case 23.—Represents the starch of the red sorgho, most of the grains of which exhibit a polygonal outline,

Fig. 533.



Case 23.

Case 24.

Case 25.

Case 26.

and measure 30 thousandths of a millimetre. The amylaceous organization of the *Cactus pereskia grandiflora* are of the same size, as also that of the *Naïas major*.

Case 24.—Starch grains of the *Aponogetum dis-*

tachym of a truncated polygonal form; they measure 22 thousandths of a millimetre. Such also is the dimension of the starch contained in the stem of the *Ginkgo bilobi-salibnria adianthifolia*.

Case 25.—Exhibits the same swollen by a solution of soda.

Case 26.—Shows the starch of the *Cactus cercus grandiflora*, and which measures 20 thousandths of a millimetre.

Case 27.—Fecula of the *Cactus Braziliensis*, showing the double and triple grains; it measures 18 thousandths of a millimetre.

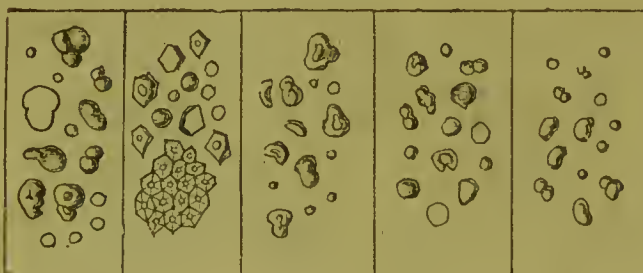
Case 28.—Starch of the *Panicum Italicum* in polygons; measures 16 thousandths of a millimetre.

Case 29.—Fecula of the *Cactus flagelliformis*, measures 15 thousandths of a millimetre. The pollen of the *Globba nutans* has the same dimension.

Case 30.—Starch of the *Echinocactus crinaceus*, measures 12 thousandths of a millimetre. Pollen of the *Rupia maritima* is 11 thousandths of a millimetre.

Case 31.—Starch of the *Cactus opuntia tuna* is 10

Fig 534.

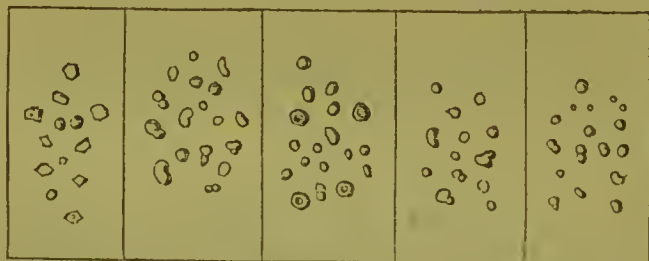


Case 27. Case 28. Case 29. Case 30. Case 31.

thousandths of a millimetre. The starch of the *Ficus indica*, as also that of the *Cactus cnrassavicus*, have the same dimensions.

Case 32.—Starch of the *Aylanthus glandulosa* measures 7 to 8 thousandths of a millimetre.

Fig. 535.



Case 32. Case 33. Case 34. Case 35. Case 36.

Case 33.—Represents the starch grains of the *Cactus cnrassavicus*.

Case 34.—Starch from the parsnip, measuring 7 thousandths of a millimetre.

Case 35.—Shows the granules of the *Ficus indica*.

Case 36.—Shows the double starch granules of the *Cactus serpentinus*, 7 thousandths of a millimetre.

Case 37.—Fecula of the *Cactus monstrosus*, measuring 6 thousandths of a millimetre.

Case 38.—Millet starch—*Panicum miliaceum*—exhibiting the polygonal form; they measure 9 thou-

sandths of a millimetre. The inclosed grains are those that have been swollen with a solution of soda.

Fig. 536.



Case 37. Case 38. Case 39. Case 40. Case 41.

Case 39.—Starch of the *Cactus mamillaria di* exhibiting several double grains; length 8 thousandths of a millimetre.

Case 40.—Starch grains of the sugar beet, exhibiting a globular form; the largest measure 4 thousandths of a millimetre.

Case 41.—Starch from *Chenopodium quinoa*, of rounded form, measuring only 2 thousandths of a millimetre.

Thus it will be seen, that the most general forms of starch corpuscles are ovoidal, conical, and polygonal; the first and second shapes prevail when the cellular structure, in which the granules are inclosed, offers sufficient space and retains as much moisture as to confer elasticity upon the coats and interior substance of the grain; but sometimes the granules are collected in large numbers in the cells of the seed or plant, which in turn are closely bedded in the *testa* or outer covering; in such cases—as shown in Case 13 in preceding plate—the compression causes the walls of the amylaceous bodies to assume polygonal forms.

SCHLEIDEN and others describe the formation of a starch corpuscle as commencing from a spheroidal granule, the nature of which is assumed to be different from the matter subsequently secreted. This matter, according to PAYEN, is assimilated through a funnel-

Fig 537.



Case 1.

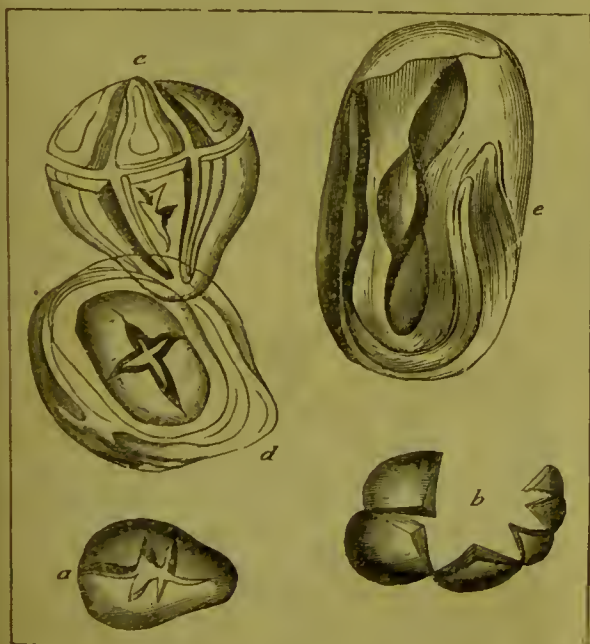
Case 2.

shaped opening in the granule, usually, though improperly, called a *hile* or *hilum*. This aperture is visible in many varieties, and sometimes grains are found to have two or three of them, especially when the

corpuscles are large; and even when imperceptible under the usual magnifying powers, they may be rendered visible by submitting the starch to careful desiccation, when the internal matter contracts, and thus causes an enlarged opening, which, sinking into the granule, exhibits the rings or discs usually observed in starch grains abutting against it, as seen in the annexed figure, exhibiting in Case 1 the starch granules with the hilum, and, in Case 2, the same after desiccation. These concentric rings or bands have led to much controversy as to the true organization of the starch corpuscle. It is generally supposed that it is made up of layers superimposed on one another, from the nucleus to the outer wall, and that the bands contracting towards the hilum result from the upper verge of such layers cropping out. Those maintaining this view hold that the matter in each differs neither in its nature nor composition, beyond being a little denser as the outer surface is approached. Those who maintain the opposite opinion assert that the corpuscles are true cells filled with the true amylaceous matter, and that the bands are simple plications of the walls of the cell.

When starch is moistened with alcohol of 0.85 specific gravity, and then slightly heated, the spirit evaporates readily, and leaves a slight particle of water

Fig. 538.



on each grain, which, at the increased temperature, is acted upon more or less; and if the grains be placed in an excess of the liquid so as to remove the entire mass, nothing but a thin pellicle remains. Fig. 538 exhibits granules of potato starch thus treated; the granules, *a*, *b*, *c*, show the effect of the action of the drop of water; *d* shows the partial solution of the substance leaving the insoluble portion; and *e*, the swollen insoluble pellicle. According to Busk, the best method for exhibiting the starch corpuscle under the microscope is, to saturate it with a concentrated solution of chloride of zinc containing a little free iodine. No change appears from these agents; but as soon as water is added, the grains assume a deep-blue color,

and gradually expand, developing at the same time a frill-like plicated margin, which slowly opens out; the plications on the globule may then be seen slowly unfolding, and may be traced in many cases into the rugæ of the frill. Ultimately the granules swell up to twenty or thirty times their original bulk, in which state they appear as flaccid sacs, though no extrusion of matter can be observed during the experiment.

The Editor finds REID argues, from the following endosmotic experiment, that the starch has an exterior covering or cellular membrane coating the inner substance, and that the latter is not organized in successive layers as if a number of sacs were arranged one within the other. He saturated starch granules with glycerin, and placed them while in this state in contact with water, when endosmotic changes followed, the less dense liquid being absorbed. After the absorption the grains were found to have burst in the direction of their axes, the rupture indicating a membrane that had been corrugated by release from unusual tension, whilst the covering of the remaining portion of the granule was visible in distinct longitudinal wrinkles from the hilum downwards. He submits that, were the corpuscle composed of superposed laminae only, the addition of water in the manner described ought not to rupture it, or if this happened, the fracture would be in the direction of the laminar surfaces and not at right angles to them or their supposed order, as happened in his experiments. He further holds that the bands or lines observed in starch grains are mere plications of the outer membrane, because they entirely disappear on swelling the corpuscles with any liquid.

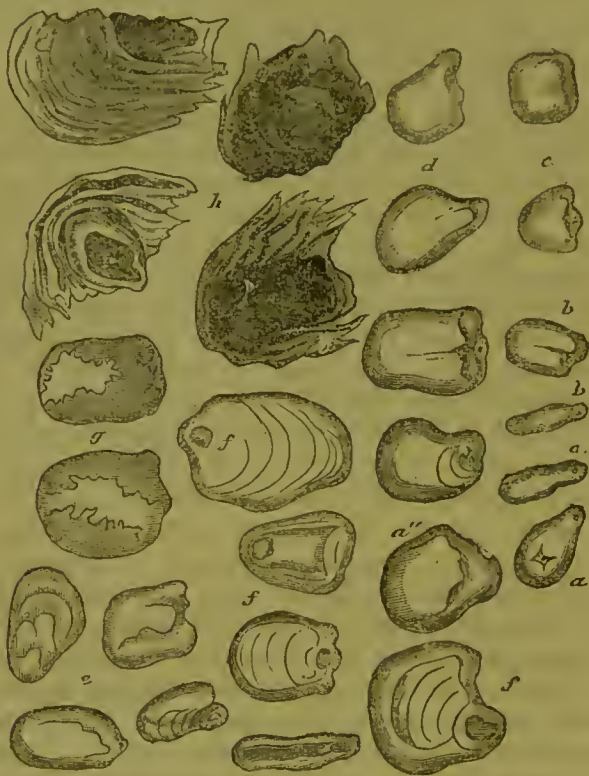
In direct opposition to this view may be placed the facts already stated of the combined effect of heat and solvents. Thus, if a little potato starch be heated on a metal plate to 360° or 390°, and then examined after treatment with a little water, the several layers will be found swollen, and by adding an aqueous solution of iodine they will be made to appear with considerable distinctness. The question, however, is not yet thoroughly answered, though the mass of evidence is in favor of the view that an outer cuticle surrounds the inclosed matter, from which, as well by the iodine reaction as by its less solubility, such coating differs in many of its properties.

In the annexed woodcut—Fig. 539—*a*, *a'*, *a''*, *c*, *d*, represent granules of starch heated to 320°, 392°, and 410°, as seen in alcohol; *f*, *f*, the same swelled in water after being heated to 320°, showing the hilum opening inwardly; *g*, granules of the same starch submitted to the last-mentioned temperature and afterwards plunged into alcohol, which, on evaporation, left a little water on the external part of the grain, and which dissolved a portion of the exterior matter; *h*, grains of starch heated between 392° and 420° and then put in water, when they swell to such a degree as to exhibit the different folds of their matter in the form of so many layers. These folds are more easily distinguished by adding a little of an aqueous solution of iodine to the liquid, in order to give them a violet tint.

Before passing to the consideration of the chemical properties of starch it may be well to give, in addition

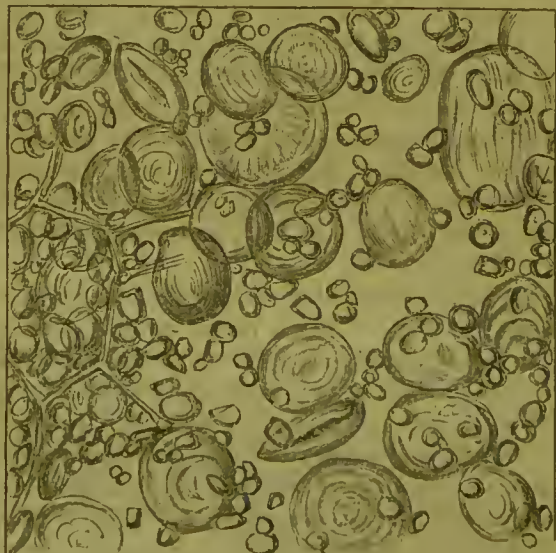
to the descriptive references in the preceding drawings, a few additional facts concerning those starches which form articles of commerce.

Fig. 539.



WHEAT STARCH.—The amylaceous corpuseles of wheat differ somewhat among themselves in appearance and size of grain, but generally they are composed of

Fig. 540.

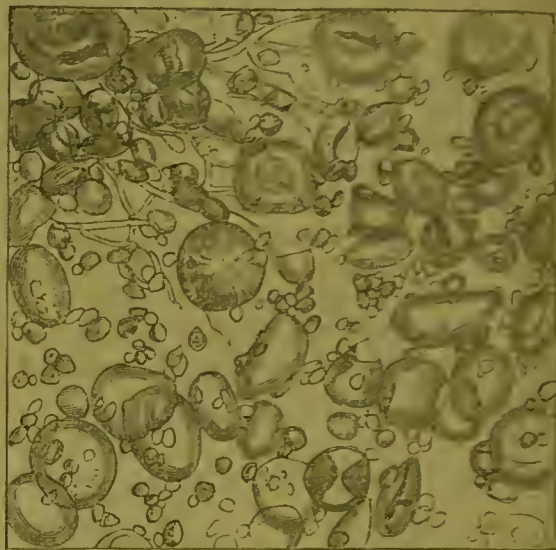


large and small granules, with very few of an intermediate size. The smaller grains are chiefly round, rarely oval, and for the most part provided with the dark central spot or aperture designated the hilum; the large granules are rounded and flattened, so as to give them a lenticular appearance. In most of the grains neither the hilum nor the concentric rings can be distinguished with a magnifying power under four

hundred and sixty linear diameters. Viewed obliquely between glass plates, some of the grains seem ring-shaped, and present the appearance of a longitudinal furrow, occasioned by the partial folding or curling of the grain on itself; this has been erroneously described by PEREIRA as the hilum. In Fig. 540 are represented the structure and appearances of the granules of wheat flour, as also the characters of the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

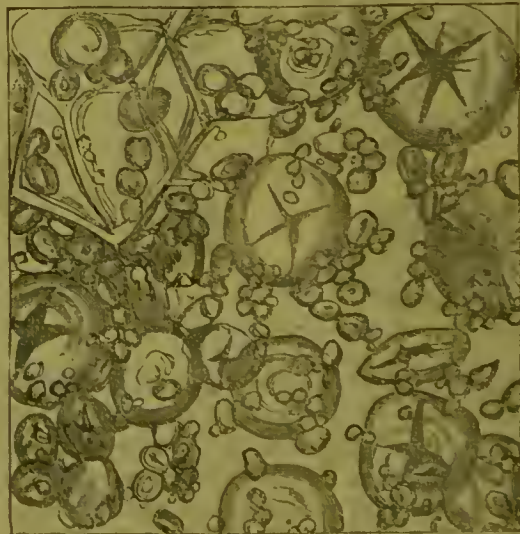
BARLEY STARCH.—Fig. 541—is somewhat different from

Fig. 541.



that of wheat, being composed of large and small grains; but the latter are three to four times less than the corresponding ones of wheat starch. This engraving represents the structure and characters of barley starch, together with the cellulose. It is drawn with the

Fig. 542.



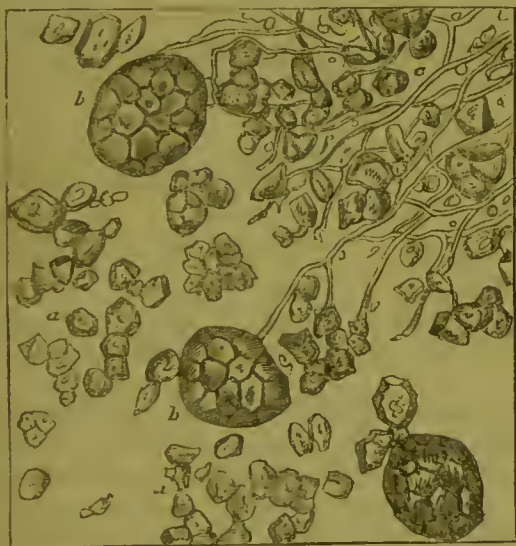
camera lucida, and magnified one hundred and forty diameters. A considerable number of the large corpuseles has distinct rings and the furrow already referred to.

RYE STARCH.—This variety—Fig. 542—is similar to wheat starch in the form of the granules, but the smaller grains appear to be less than the analogous ones in wheat starch, and the others somewhat larger. In

addition to these differences, there is seen on the flattened surfaces of the larger grains of rye starch a three or four, or even five-rayed hilum or spot, which serves at once to distinguish the two varieties. This engraving represents the structure and characters of the starch granules of rye flour. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

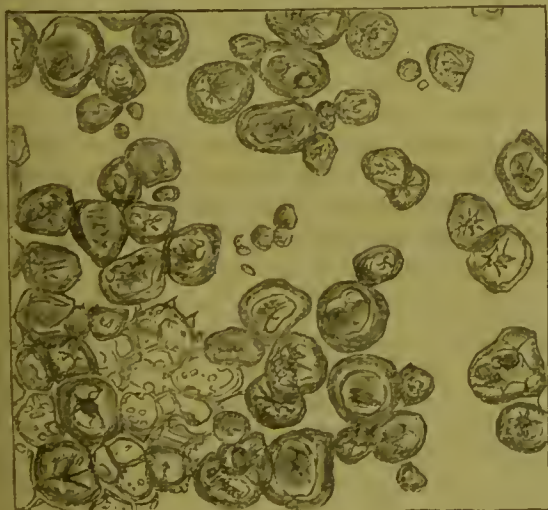
OAT STARCH.—The corpuscles of this variety—Fig. 543—are much smaller, but more homogeneous, than those of wheat or barley; and instead of being circular, they have a polygonal outline, and are devoid of visible rings or hila. Many of the granules remain connected, presenting rounded or oval bodies, with a reticulated

Fig. 543.



surface, indicative of their structure. Another well-marked difference is, that the granules of oat starch do not show the usual crosses when viewed with polarized light that the other cereal starches exhibit under the

Fig. 541.

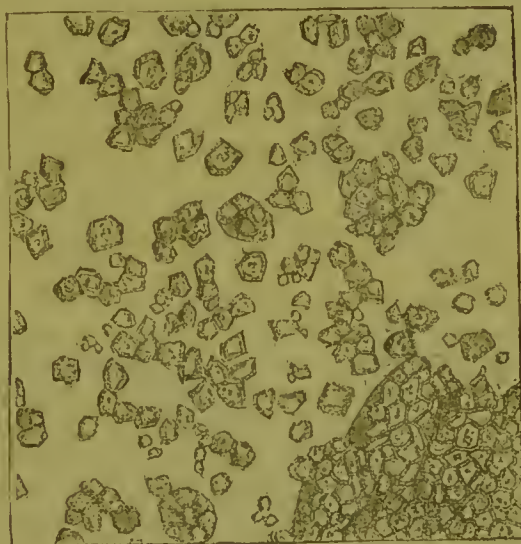


same circumstances. This engraving represents the structure and characters of the starch corpuscles of oat flour, as also of the cellulose. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

MAIZE OR INDIAN CORN STARCH.—This—Fig. 544—resembles in a great measure oat starch in the polygonal outline of its granules, but the corpuscles are much larger, and do not aggregate to form compound bodies, as is the case with oat starch. Under the polariscope maize starch presents well-defined crosses, and, like all the other amylaceous organization of the cerealia, exhibits the central depression of the grains very well marked. This engraving represents the structure and characters of the starch granules of Indian corn flour, including the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

RICE STARCH.—This variety—Fig. 545—representing the starch corpuscles of rice flour, drawn with the camera lucida, and magnified four hundred and twenty diameters—presents the appearance of very small polygonal grains, more angular, however, than that of the

Fig. 545.



oat or maize; it has a well-marked central depression in the grain, the edges of which appear raised. They resemble the starch from the oat grain, by their aggregating together and forming in rounded masses. The preceding figures, representing the starches referred to, are taken from HASSALL'S *Adulteration of Food*.

CHEMICAL PROPERTIES OF STARCH.—Viewed chemically, starch may be regarded as a definite compound of water and the true principle of organic formation bearing this name, or *amylum*. If the substance, after extraction from the plant which yields it, be allowed to deposit from the water in which it is held in suspension and then dried by pressing between absorbent media, such as plaster of Paris, till no further loss is sustained, it will be found still to retain forty-five per cent. of its weight of moisture. On exposing this product to moist air at a temperature of 68°, the weight of water will ultimately be reduced to thirty-five per cent. At this degree of desiccation the starch appears of snow-white brilliancy, possessing remarkable cohesive properties, so much so as to allow its being readily pressed into plates possessing a considerable degree of tenacity, and capable of receiving an impression from hard bodies without, however, yielding any moisture to an envelope

of bibulous or other paper in which such plates may be inclosed. It is impossible to sift it whilst in this state, and when projected upon metal plates, heated to 300° , the particles agglutinate into compact masses. This property is turned to account in the manufacture of tapioca, sago, and the compounds sold as patent soluble starches, from ordinary fecula or wheat starch.

When the starch which has been desiccated in moist air for several days, is exposed to the circulation of a dry atmosphere, it parts with a further quantity of water, which reduces the per centage of that ingredient to eighteen, and in this state it possesses a very slight adhesive property, but not to such an extent as would prevent it from passing through the meshes of a fine sieve; neither does it swell up or agglutinate as before. Thus dried, it constitutes the ordinary commercial starch. Air-dried fecula of this nature loses a further quantity of moisture when kept in a vacuum at a temperature of 60° , so as to leave only fifteen per cent. combined; and if the heat be sustained at 260°

the moisture is reduced to a minimum, or eight and half per cent. Starch so dried constitutes a monohydrate of amylin or of the true starch principle, from which mere desiccation cannot remove more water without altering or destroying the order of combination of the elements entering into its composition. It is only by combining the matter of starch with metallic bases, such as lead or baryta, that it can be obtained in a perfectly dehydrated state, in which it exhibits upon analysis the following composition, corresponding with the formula $C_{12}H_9O_9$:—

	At. Weight	Cent.
12 Eqs. of Carbon = $12 \times 6 = 72$	47.15	
9 " Hydrogen = $9 \times 1 = 9$	5.88	
9 " Oxygen = $9 \times 8 = 72$	47.15	
	153	100.00

By tabulating the results above referred to, the relation between the amylaceous matter and the combined water will be more easily comprehended :—

Condition of Starch.	Formula.	Atomic weight of Starch.	Per centage of H ₂ O in thoroughly dried starch.	Per centage of monohydrate of starch.
Anhydrous amylin,.....	$C_{12}H_9O_9$,	153	0	0
Starch dried at 212° to 280° in <i>vacuo</i> ,.....	$C_{12}H_9O_9HO$,	162	0	100
Starch dried at 60° in <i>vacuo</i> ,.....	$C_{12}H_9O_9HO$, 2 aq.	180	10	90.0
Starch dried at 68° , in air containing 0.6 per cent. of moisture, ...	$C_{12}H_9O_9HO$, 4 aq.	198	18.18	81.82
Starch dried in air saturated with moisture,.....	$C_{12}H_9O_9HO$, 10 aq.	252	35.71	64.34
Starch thoroughly drained by absorbents,.....	$C_{12}H_9O_9HO$, 15 aq.	297	45.45	54.55

When subjected to a heat ranging from 395° to 410° , starch is readily converted into dextrin, but some kinds are more easily acted upon in this way than others. If a certain amount of water be contained in the starch, the heat necessary for its transformation is not so great. Thus, when starch dried in a vacuum at 260° is subjected to a temperature of 320° in an oil bath, it does not suffer much change, and retains its property of insolubility in cold water; but when the temperature is raised to 395° , and sustained at this degree for half an hour, the starch becomes altered to an amber color, without, however, giving out much water, and the chief part is dissolved by cold water. It is different with fecula containing four equivalents of water, which, if suddenly brought to 320° to prevent the evaporation of the moisture, passes at this degree into dextrin, so that the effect is in all things nearly the same as if the substance were quickly heated in the air to 395° or 410° . According to JACQUELIN, the changes that follow an increase of temperature applied to starch merely air-dried are these :—From 212° to 284° the hilum is more and more developed, appearing in the end like a large rent or tear; at 320° the granules lose their ordinary form; at 338° the inclosed starchy matter becomes soft and slightly colored; at 356° it turns black, and is soluble; and at 372° to 395° the walls of the grains burst asunder.

Such are the changes which heat alone effects upon starch; they are somewhat different from those that are produced by other agents.

Potato starch or fecula suspended in twelve to fifteen times its weight of water suffers no change, not even when the temperature is raised to 131° , with the exception of a slight increase of the younger or more

tender grains; at 135° , however, the corpuscles perceptibly swell, and continue to do so as the heat advances; at 162° the increase of the granules becomes more evident, and the liquid assumes more or less consistency, which goes on increasing up to 212° , when it forms a paste of greater or less thickness. If the proportion of the fecula and water be as one to a hundred and the mixture be boiled, the white color of the corpuscles disappears and the whole presents a perfect solution, so much so as to traverse a compact filter; yet a finer filtering medium can separate the starch so as to make it appear that, instead of being dissolved in the liquid, the corpuscles were only largely distended and diaphanous. PAYEN, by immersing the bulb of a hyacinth in such a filtered solution, succeeded in separating the apparently dissolved starch: for there appeared, as the rootlets absorbed the water, particles of starch adhering to them, which were turned blue by iodine, whilst a section of the roots of the bulb gave no indication with this test of the presence of amylaceous matter. Hence it is evident that the fine capillaries of the plant, being too small to permit the passage of the particles of starch, caused their accumulation on its surface—a circumstance which, it may be supposed, would not occur if the starch were perfectly dissolved. Not only is the starch separable from its apparent solution by the means just mentioned, but it is precipitated by cold even when the quantity of water is more than double that mentioned in the last experiment. By submitting starch paste made with fifteen parts of water and one of starch at 212° , to cold sufficient to freeze it, and then allowing it to thaw, a contraction of the paste takes place, and it parts with a portion of its water. By repeating the operation, the

starch, which was apparently soluble in water whilst in the form of paste, becomes quite insoluble, and precipitates from the liquid in flakes. Advantage is taken of this property to obtain a felt-like substance suitable for certain kinds of cartridges, and for other purposes to which paper is inapplicable. The paste, after being cooled below zero, is then heated slightly above the freezing point and submitted to pressure, when most of the water is expelled and a dense felt-like matter remains, applicable for the above uses. Even when the quantity of water in which the starch is boiled is two or three hundred times greater than the weight of the starch, it is found that by repeatedly freezing and liquifying, the menstruum and the starch separate in flakes. From all these circumstances it appears doubtful whether starch is entirely soluble in hot water.

Solutions of the fixed alkalies have the effect of swelling the corpuscles of starch, and causing it to form a paste even without the aid of heat. Mixed with an alkaline solution containing from one and a half to two per cent. of alkali, the starch granules appear to swell, when viewed under the microscope, to the extent of seventy-five times their original bulk. By previously drying the starch *in vacuo* till it becomes a monohydrate, the absorbent qualities seem to be considerably increased, for when such fecula is treated with a liquid containing only one per cent. of alkali or less, the enlargement is so great as to rupture the cell walls of the grains, and cause the starchy substance or amylin to protrude and become diffused in the liquid.

When the quantity of alkaline water is not in too great abundance, it converts the starch into a semi-transparent paste, in the same manner as water. It would appear that a salt of the alkali is produced in this operation, in which the starch forms the radical, and from which the insoluble amyates of the alkaline earths or metallic bases may be obtained by simple double decomposition, upon the addition of a neutral soluble salt of those bases. The decompositions in these cases are so complete that, when an equivalent of the precipitant is employed, the filtrate from the precipitate does not, upon the addition of iodine, give the slightest indication of the presence of starch; the iodine will not give the usual reaction of starch with the precipitates till after their decomposition with a weak acid, such as acetic.

From the analysis of the amyates of lime, baryta, lead, and silver, the composition of the true matter of starch, as previously stated, has been deduced.

Sulphuric, hydrochloric, and nitric acids in a diluted state have also the power of swelling starch and converting it into a paste. When sulphuric acid is employed, the proportion of acid in the liquid should form at least three per cent. of strong acid. If, in addition to the effect of dilute acids, the temperature of the solution in which the starch is held be raised to 212°, several changes follow, the first of which is the production of dextrin, a substance isomeric in composition to the true amylaceous matter that is soluble in cold water, and in its properties analogous to gum; the next change appears to be the formation of glucose or grape sugar, a body which differs from starch merely by two equivalents of water, or rather of oxygen and

hydrogen; for these elements are assimilated so that they constitute an integral part of the new compound. Its formula is $C_{12}H_{12}O_{12}$, but as it crystallizes from the liquid it takes two equivalents of water of hydration, in which state it may be represented as $C_{12}H_{12}O_{12} \cdot 2HO$ or $C_{12}H_{14}O_{14}$. These changes take place to a large extent with starch paste made simply with water by the aid of heat, by mere exposure to the air. Thus one hundred parts of wheat starch made into a paste with twelve hundred of water, and the mixture exposed during thirty-eight days, was found by SAUSURE to yield—

Sugar,	47
Dextrin,	23
Starch granules,	8
Starch,	4
„ altered,	10
	—
	92

The difference in this instance must be attributed to the change in the composition of the substance. This was shown by taking the same weight of starch, treating it as above, and allowing the same period of exposure; it was then analysed, and the results showed a loss of one fifth, thus :—

Sugar,	50
Dextrin,	10
Starch granules,	5
Starch,	4
„ altered,	9
Carbonaceous matter,	0.3
	—
	78.3

A disengagement of carbonic acid accompanies this decomposition when it takes place in the air; if on the contrary, the reaction take place in close vessels, bubbles of hydrogen are evolved from the mixture. In these cases it is probable that the small proportion of gluten in the starch, generating diastase by decomposition, renders the change more active; for it is well known that diastase will convert starch into dextrin and sugar, to the extent of two thousand times its weight.

The starch granules mentioned in the preceding analysis are such as settle down from a solution of starch in water at 300° when the liquid is left to cool; these granules are dissolved in water at 160°, or better when the heat is so high as 212°, and the liquid affords the ordinary reaction with iodine. It appears from the experiments of JACQUELIN that they are permanent, and may be reproduced from their solution in boiling water by simple evaporation in their original form; they are insoluble in cold water, as may be proved by iodine, but when rubbed in a mortar and then diluted with water it is probable that some of the grains are fractured, for on testing the liquid it manifests the presence of starch. The best method for obtaining this permanent form of starch is to digest a mixture of one part of fecula and five of water in a PAPIN's digester at 300° for two hours, and afterwards to allow the mixture to cool. Should the heat rise to 320° the fecula would be converted chiefly into dextrin, with a little sugar giving a violet color with iodine; on the other hand, if the heat approaches 355° the sugar predominates and very little dextrin is found, so that iodine has no effect upon it.

It has been already mentioned that dilute nitric acid converts starch, equally with dilute sulphuric acid, into dextrin and sugar, after swelling the granules and transforming them into a pasty mass, when the water is not in excess. The result of the action is very different when strong nitric acid is employed. BRACONNOT found that fuming nitric acid, specific gravity 1.5, when poured upon starch or fecula, dissolves it, and on the addition of a large quantity of water a substance was precipitated, which, when freed from excess of acid by washing and dried, proved to be highly inflammable and soluble in ether; this is the xyloidin or nitramidin of PELOUZE, who found it to be composed of one equivalent of starch with one of nitric acid. With the same acid, and the application of heat, starch is converted into a number of indefinite substances, which ultimately resolve themselves into oxalic acid. This operation, with slight modifications, is followed in the manufacture of the latter article as will be seen by referring to page 637 of this volume.

Hydrochloric acid causes the alterations of starch already mentioned into dextrin and glucose, first forming a jelly, or dissolving the substance according as the quantity of water present is greater or less. Its action is far less energetic, however, than chlorine. The latter element has invariably a decomposing action upon starch, which results in the production of water and carbonic acid. These changes take place even when a solution of hypochlorite of lime—bleaching powder—is put in contact with starch in the cold, but the decomposition is gradual. With an excess of the reagent the transformation is more rapid. Oxalic, tartaric, and other acids have the power of swelling the starch grains, and ultimately converting them into dextrin or glucose. Acetic acid is devoid of this power, and therefore the fecula remains quite unaffected by it. The same inertness is exhibited by ammonia towards this body, and hence the following method by PAYEN, for the valuation of vinegar and ammoniacal salts:—He adds about a five-hundredth part of the sample of ammoniacal salt to be tested, of starch to the solution in which the former is contained, and then drops in a standard liquid of caustic-soda till the menstruum indicates the swelling of the granules and the formation of a paste. Previous to this result, the soda displaces the ammonia by combining with its acid; but after the whole of the ammoniacal salt is decomposed, the soda that is added in excess reacts upon the starch, and converts it into a paste. Vinegars unadulterated with mineral acids have no action upon starch, so that when a mixture of the two is boiled, the peculiar reaction of starch and iodine is exhibited unchanged; but if the acid be adulterated with sulphuric or any other mineral acid, the change of the fecula to dextrin and glucose will be proportionate to their quantity, and this alteration will be exhibited by the iodine reaction. The tests, however, considered analytically, are of little value.

The most remarkable property of starch is the combination it forms with iodine, and which is characterized by the well known blue color of the compound.

This reaction, besides being the most sensitive test yet discovered for the mutual detection of starch and

iodine, has many other important applications with reference to the changes which the fecula undergoes and the influence of other agents. When a weak solution of iodine is added to starch the blue coloration takes place, but it is so superficial that the granules appear transparent when observed under the microscope. If the quantity of iodine added be greater, the coloration becomes more intense, and to such a degree as to cause the corpuscles to appear black; this blackness and opacity take place when only one two-thirtieth of a millimetre in thickness. As the combination proceeds through the entire mass of the granule, the whole appears of a beautiful blue. Between this characteristic blue shade, every gradation of tint is observed till a reddish or orange color manifests itself, according as the starch is disaggregated and changed into dextrin and sugar under the influence of a hot solution acidified by sulphuric acid, or any other body capable of producing the like effect. Thus, a solution of starch in boiling water, when iodine is added immediately forms a fine blue precipitate; and then by pouring in some sulphuric acid, and maintaining the heat, it gradually changes to various shades of violet, afterwards to wine-red, then to a crimson-red, and finally to an orange-tint. Some of these shades are produced when iodine is added to starch in its progressive stages of development. Young or imperfectly formed starch granules, in which the matter is not properly aggregated, produce with iodine a reddish-fawn color; and as the particles become more united and compact the tint changes through the several stages of violet, in which the blue predominates, till ultimately, as the granules are fully formed, the tint resembles that of indigo.

There are many evidences that the result of this action is a true combination of the starch and iodine. If the compound be kept at 60° *in vacuo*, it retains nearly as much water as the starch itself under the same treatment. When the compound is partially desiccated in the vacuum, and the heat is afterwards raised to about 425° to 430°, a portion of the iodine is expelled, but on cooling the substance again by contact with the air, the shade of color still remains very deep. On adding a little water to the compound, and repeating the experiment under the same circumstances, a further amount of the iodine is displaced though the color is not eliminated. Treated with water at this stage of the experiment, only about two per cent. of the starch is dissolved, and this soluble portion even strikes a violet color upon the addition of a little iodine. Upon examination, many of the granules of the insoluble portion are so highly tinted as to appear black, and these resist the action both of the alkalis and concentrated sulphuric acid in the cold, thus showing that a very strong combination has taken place.

Starch dried at 212° to 266° in a vacuum, and suspended in absolute alcohol, does not unite with iodine dissolved in the same menstruum; but if a little water be added, a violet coloration, which deepens in shade by standing, is immediately produced. From this behavior it might be anticipated that alcohol would abstract iodine from the amylaceous compound. This is to a great extent the fact, for on agitating the blue

compound with about twenty times its weight of absolute alcohol, and decanting the liquid after the matter subsides, a portion of the previously combined iodine will be removed; and by a repetition of the process, fresh quantities will be taken up, though less each time, till as much as four-fifths of the combined iodine is separated. When the solvent is employed at the boiling temperature, the decoloration is much more rapid; and if a portion of the substance be viewed under the microscope whilst the reaction is taking place, it will be noticed that the least aggregated of the corpuscles, or in other words, the younger ones yield their iodine first, and turn to a violet and red color. The granules of starch do not lose their distinctive character by combining with iodine, for if the blue iodide, dried thoroughly at 212° in a vacuum, be examined under the microscope in the presence of absolute alcohol, the corpuscles will, as they become decolorized, appear intact. If, however, a few drops of water be added to the alcohol employed whilst the substance is under examination, or after it has been dried, several of the grains appear as if burst; the inclosed matter being disseminated in the liquid and colored reddish-violet, the coats of more aggregated matter acquiring by the hydration a shade approaching to a blue.

The blue iodide of starch is decomposed by several agents. Exposed to the light of the sun, it gradually loses its blue color in the presence of water; the effect is more rapid when the menstruum is raised to a temperature of between 86° and 105° . In either case the changes result from the decomposition of water, the hydrogen of which enters into combination with the iodine to produce hydriodic acid, the oxygen forming iodic acid with another portion, so that the mixture becomes colorless. When starch is freshly treated with iodine, the alkalies readily decolorize the compound, owing to an iodide and iodate of the alkali being produced, leaving the starch almost intact in the solution. It is a very curious characteristic of the iodide of starch that, by a change of temperature alone, the blue color may be made to disappear and return several times in succession. If an excess of iodine be poured into the solution of starch the blue iodide will be retained for some time, even at 212° ; but when the excess of this element is volatilized by the heat, the compound fades, and even a heat not exceeding 160° will be found capable of reducing the color of the mass completely. On allowing the vessel to cool, however, the blue tint, strangely enough, reappears, and this alternation of color can be repeated by heating the solution, and allowing it to cool again. By degrees, the tint weakens each time the solution is cooled, owing doubtless to the loss of iodine sustained either by expulsion in the form of vapor, or by conversion into hydriodic acid. The blue tint is retained with much greater tenacity when the amount of starch present is greatly in excess of the iodine.

Iodide of starch precipitates very readily from its solutions however dilute; but the coagulation of the matter takes place much more readily in presence of the neutral salts of the alkalies and alkaline earths, and of dilute acids, and even by a reduction of temperature. In all of these conditions the separation is to

be attributed to a very marked contraction which the iodine by its union causes in the corpuscles of starch.

It has been stated that water at a high temperature, acid, and alkaline solution have the power of swelling the granules of starch to such an extent as to render them apparently soluble when the volume of water is very large, or to produce a semitransparent jelly, when its quantity does not exceed a certain limit. In the latter case the increase in the granules is greater than the volume of the liquid in which they are held; and, consequently, instead of moving freely as in a solution, the swollen grains are compressed and ramify into one another till the whole becomes as it were soldered—at which stage the mass appears a jelly. When iodine is added to such a mass a reverse change succeeds; and the contraction of the grains enables the compound to precipitate readily, so that, in a short time, the blue iodide will be retained on a filter from the liquid portion. In a very dilute solution of starch the precipitation of the iodide is not so rapid as in menstrua of greater density. Congelation, in such cases, causes the blue compound to form in floeculi in the liquid; and in time they settle to the bottom, leaving the rest of the liquid colorless. Cold has an analogous effect upon fecula which has been distributed in a large quantity of water, and subjected to a temperature of 212° ; for, by repeated freezings and solutions of the frozen mass, by successive applications of cold and heat, the starch grains which before had seemed as if dissolved, owing to their great extension, now appear in flocks in the liquid, and can be separated from the latter by simple filtration. In both cases a considerable amount of contraction takes place, to which the separation of the starch, in one instance, and of its iodide in the other, is to be attributed. One equivalent of iodine can fully saturate seven of starch in producing the blue iodide; the ratio of combination between them is therefore as seven to ninety-two by weight, and by volume as one to twelve.

Tannic acid seems to form combinations with solutions of starch, giving a greyish-white flaky precipitate, which becomes transparent in the heat, but reappears in the usual form as the liquid cools. This acid decolors the blue iodide of starch, and when present in sufficient quantity it prevents the entire decomposition of fecula by means of diastase. The reaction contributes in part to the formation of artificial leather on CLAUSSEN'S principle, as already detailed in this work.

Amount of Starch contained in different substances.

—The quantity of starch in different grains and bulbous roots yielding this substance, varies considerably, both in the per centage, amount, and gross total yield per acre; and these two circumstances must be taken into consideration by the manufacturer in selecting one in preference to another of the many sources whence the starch is extracted. Thus while the potato affords centesimally only from fifteen to sixteen parts of starch, wheat affords as much as sixty per cent.; still the total amount per acre is in favor of the potato in the ratio of 2400 to 996; the produce being estimated at six tons in the first instance, and sixteen hundred-weight in the latter.

Different varieties of the same species of grain likewise exhibit a marked difference in the amount of starch, as appears from the following table:—

AMOUNT OF STARCH IN DIFFERENT KINDS OF WHEAT DRIED AT 212°.

	Per cent.
Talavera wheat from Hohenheim,.....	56·25
Whittington " ".....	52·45
Sandomierz " ".....	53·37
Wheat from Giessen,.....	54·63
Do. from Vienna, No. 1,.....	65·68
Do. " No. 2,.....	67·17
Do. " No. 3,.....	67·45

A difference as remarkable is exhibited in various kinds of potatoes. Thus JOHNSTON found in—

	Per cent.
Red potato from Lanarkshire,.....	14·08
Small Americans,.....	17·80
Orkney potatoes,.....	17·42
Buffs from Forfarshire,.....	20·71
Kidneys,.....	14·93
Cups from Argyleshire,.....	15·41

Mr. HEMING gives the following numbers as the percentage of starch from different varieties of potatoes grown on the same soil in Renfrewshire, namely:—

	Per cent.
Irish blacks,.....	16·5
Connaught cups,.....	21·0
White dons,.....	13·0
Red dons,.....	10·75

This variation is the more remarkable when considered with reference to the quantity produced per acre:—

	Quantity per acre.	Amount of starch.
	Tons.	Tons.
Cups,.....	13·25	2·9
White dons,.....	18·50	2·4
Red dons,.....	14·25	1·5

It may be presumed that much of the discrepancy in the quantity of starch indicated by the foregoing analyses is to be attributed to the age of the tubers; but though the amount of fecula certainly varies at different periods in the growth of the plant, still the experiments that have been made to elucidate this question conclusively demonstrate that even at maturity the quantity of the starch is unequal. The per centage of starch which any given variety yields, depends very much likewise upon the nature of the soil and the weather which has prevailed during harvest, the yield being much less in dry than in wet seasons. Potatoes that have been allowed to remain a considerable time in the ground, or being improperly stored, have become heated and budded, will not be found to contain as much fecula as others of the same kind which have been timely collected and carefully stored; for the sprouting effects the decomposition of a considerable portion of the starch. This is well known in potato-starch factories; for whilst, in the months of October, November, and December, as much as seventeen per cent. is obtained, in January, February, and March, the amount diminishes to fifteen and even twelve per cent.

There is no difficulty in inferring from these facts the advantage gained by extracting the fecula from potatoes during the three months after they have arrived at maturity, rather than at a more advanced

season. Analysis of the potato shows that it is composed centesimally of—

Water,.....	74·00
Fecula,.....	20·00
Epidermis, cellular tissue, pectose, pectates of lime, soda, and of potassa,.....	1·00
Albumen and analogous nitrogenous matters,.....	1·50
Asparamide,.....	0·12
Fatty matters,.....	0·10
Sugar, resin, essential oil—ecalanine,.....	1·07
Citrate of potassa, phosphates of potassa, of lime and magnesia, silica, alumina, oxide of iron, and manganese,.....	1·50

100·00

The following numbers indicate the percentage of starch in the various cereal grains, which can be employed for the manufacture of starch, and in the potato according to KROCKER's analyses:—

	Cereal grains.
Wheaten flour,.....	65·21 66·16
Rye,.....	61·26 61·56
Oats,.....	37·93 36·90
Barley,.....	64·63 64·18
Buckwheat,.....	43·80 44·45
Buckwheat meal,.....	65·05
Indian corn,.....	65·83 66·80
Indian cornmeal,.....	77·74
Rice,.....	85·78 86·63
Beans,.....	37·71 37·70
Peas,.....	38·81 38·7

	Potatoes.
	I. II.
Blue potatoes,.....	23·20 22·80
White potatoes,.....	16·14 17·98
" ".....	16·48 16·00

The potato has long been resorted to for the preparation of the cheaper kinds of starch; but, in addition to this source and wheat, from which the finer kinds are made, other matters—such as rice, maize, and barley—are employed in the manufacture. Wheat and other cerealia having been first employed, claim precedence in describing the process on the large scale, notwithstanding that at present these materials are not so generally resorted to as in former times, unless when to some extent damaged, and, therefore, not so well adapted for human food.

MANUFACTURE OF STARCH.—In the manufacture of starch from the cerealia two methods are followed, which may be distinguished as the fermentative or old process, and the chemico-mechanical, or modern and improved method. That the improvements introduced of late years in the manner of making starch possess a decided advantage over the old system, cannot for an instant be doubted, and yet in many factories the old process by fermentation is still followed; a method both noxious and wasteful. By this process, the wheat is first steeped till softened, and then coarsely ground in a malt mill, or crushed between rollers; the crushed mass is made into a thickish creamlike consistence with water, generally the acid water from a previous operation, and allowed to remain in vats or tuns for a period varying with the temperature of the weather from ten to thirty days. The effect of this prolonged steeping is to disintegrate the starch from the glutinous envelope in which it is contained in the grain; an effect produced by the gluten being partly

decomposed by fermentation, partly dissolved by the acids formed in the course of the operation, and partly by its property of becoming partially soluble on entering upon the putrefactive change. At first any sugar in the grain, or dextrin produced in the first stages of the process, is dissolved in the water, accompanied by a slight alteration of a portion of the gluten, whereby diastase is formed in more or less quantities; this sugar and dextrin are converted into alcohol and carbonic acid, and by prolonging the operation the spirit is changed to acetic acid. To equalize the action it is necessary to agitate the mass once or twice a day, and likewise to beat into it those portions which the escape of carbonic acid during fermentation may bring to the surface. After a few days the glutinous portion of the grain begins to undergo the putrefactive change more or less rapidly, and this proceeds till it is considered sufficiently advanced to allow the starch corpuscles to be separated in a state of comparative purity. By such changes, ammonia, sulphide of hydrogen, and other disagreeable products are formed, which renders the operation noxious, and often a most offensive nuisance. After the fermentation is supposed to be completed, any excess of water that may happen to be in the fermenting tun is drawn off, and the magma or thin pulpy mass is filled into bags of stout canvas, or other material, the mouths of which are afterwards well secured; they are then placed in water, and trodden upon till the water is quite loaded with starch, when it is drawn off, and its place supplied by fresh liquid; the treading is then repeated till the solution again becomes quite creamy with starch, and this, in like manner, is let off as before. Three or four such washings exhaust the bags of the starch, leaving only the husk of the grain and the altered albuminous matter, which is almost useless. The starchy liquids are made to pass through hair-cloth or wire sieves in their course to the settlers, to deprive them of any portion of husk or fragments of glutinous matter, after which they are allowed to repose in the settlers for several days; the starch sinks and forms a cake of solid matter on the bottom, whilst the more glutinous portion afterwards constitutes a deposit of a brownish color above it. Frequently, in order to delay the deposition of the glutinous matter, very light and finely-divided fibrous matters are introduced, and agitated with the liquor; the glutinous particles by attaching themselves to the fibres of the extraneous substance employed, are retained in the water a much longer time than the starch, so that the under layer of the deposit is almost in a state of purity whilst the gluten and fibre settle down upon it. After drawing off the clear water by a siphon, the impurity on the top of the deposit is separated and set aside to be washed with the next batch; the underlying portion is stirred up with fresh water, and purified by settling and decantation; this operation being repeated twice, thrice, or oftener if necessary. When the starch is sufficiently white, it is put to drain into small boxes, the sides of which are lined with flannel; or it is dug out in lumps from the bottom of the depositing vessel, and placed upon blocks of plaster of Paris, which absorb the

moisture, and thereby cause the starch to harden. The deposit in the drainer boxes is similarly desiccated before it is sent to the drying-room.

Bran, and other refuse matters of the wheat, *et cetera*, are generally mixed with the grain in these operations, and increase the amount of the product.

When the gluten is of such a nature as to agglutinate easily, it can be separated by careful manipulation, but not so, without additional labor, when it disintegrates and passes off with the starch into the water. The extraction of starch from the cereals and leguminous seeds is now much simplified by the aid of chemical substances, and consequently the older system is but rarely practised. The length of time which it required, the labor involved in the process, the loss of starch occasioned by its transformation into dextrin and sugar, and finally, the disagreeable and unhealthy effluvia which were evolved, all concurred to render the old process far inferior in every respect to the modern one. In fact the new process introduced by MARTIN offers so many advantages that one might expect it to be universally adopted by the manufacturers of starch from wheat or flour; yet the old system is still practised in a number of factories, the conductors of which allege that the product obtained from the fermentative process has a better color than that prepared by the chemico-mechanical system.

In MARTIN'S process flour is employed in preference to wheat grain or the same coarsely crushed. It is made into a stiff dough with water, and allowed to remain in that state till every part becomes thoroughly saturated with moisture. A mechanical kneader may be employed with advantage to effect this part of the work. The time allowed for the water to permeate the mass varies from half an hour in summer to two hours in the winter season. The inventor employs a trough covered with a wire-gauze sieve, No. 120, to which a pipe and tap supplies a constant stream of water for washing the dough, the water being thrown upon the mass from a rose of forty minute apertures. The workman takes a mass of dough, averaging ten pounds, and placing it under the small jets of water, kneads it on the sieve till the water ceases to flow off milky, using at first only a gentle pressure, which is increased towards the end of the operation. By this careful working, the gluten, which at first is finely divided in the dough, is made to agglutinate into a pasty elastic mass, which becomes more consistent in proportion as the starch is removed, till ultimately nearly pure gluten remains. Another mass of the dough is then operated upon in the same manner, the gluten being each time separated and removed. In this way almost the whole of the gluten is disengaged from the starch. To remove the particles of gluten which accidentally pass through the sieve, the amylaceous washings are allowed to remain for twenty-four hours at a temperature of 70° or thereabout, together with the scum which formed upon the produce of a preceding washing, with the view of inducing fermentation, and thus altering the small portions of gluten still retained. The purification of the product is effected in the ordinary way by successive washings and decantations, taking the precaution, however, to draw off the liquor when

the dense portion has subsided, and before it becomes contaminated with the lighter particles held in suspension by the glutinous matter. On allowing these washings to settle for three or four days the suspended starch falls, and is recovered after the liquor is drawn off, drained in flannel-coated boxes, and finished on plaster and the drying stove. It constitutes about ten per cent. of the starch, and, although unfit for fine white goods, it forms a very good paste for colored stuffs, dressing, and the like.

MARTIN'S process is being daily more extended, especially in Germany, with decided advantage over the old system, not only in respect to the gluten which is extracted in the fresh state, and which constitutes a fourth of the weight of the flour, but likewise as regards the starch itself; for from average wheat flour as much as fifty per cent. is obtained, whereas on the old method not more than forty per cent. could be recovered. The cause of this loss is to be found in the change which the glutinous fermentation produces on the starch, and by which it is converted first into dextrin and then through the successive stages into glueose, alcohol, and acetic acid. These changes take place more rapidly in hot weather. By the new process, the gluten separated from the starch forms the basis of another profitable business, namely, the preparation of articles of food, such as macaroni, vermicelli, semolá, and such like; or it may be compounded with other articles, such as flour or potato meal, and made into a wholesome and substantial bread. In summer the gluten separated from the starch retains its freshness fully twenty-four hours; but after this it begins to lose its tenacity, enters into partial solution, and then decomposes; in the winter season it may be retained for two days without injury.

At first it was proposed to utilize the gluten by mixing it with potatoes or inferior flour, and making the compound into bread; but subsequently it was found preferable to mix it with boiled potatoes, in consequence of the insipidity of the compounds with potato starch. The manufacture of vermicelli and macaroni did not at first succeed, in consequence of the proneness of the gluten to decomposition; but this obstacle has now been overcome, and the gluten is made into a highly nutritious and palatable food, for which purpose the patent process of VERON of Vienna is the most applicable. In this method the gluten, after the separation of the starch, is mixed with twice its weight of best flour, and placed in a machine consisting of two concentric cylinders, the inner one of which is furnished with projecting pins, and is made to revolve much more quickly than the outer; the glutinous substance is thereby divided into a mass of elongated grains, which are placed upon trays and dried in the hot-air compartment along with the starch for the space of one and a half to two hours. The whole is then sifted to separate the finer from the coarser particles, and the latter is ground in a mill and resifted. The very rich nitrogenous compound thus prepared offers advantages over macaroni and semolá, owing to the readiness with which it may be prepared into food.

Such are the main features of the process followed in manufacturing starch from wheat, grain, or flour;

the details of the manufacture will be more fully given when treating of potato starch or fecula. At present it may be remarked, however, that the different qualities of starch to be met with in the market are simply the successive deposits, or the portions which settle in succession in the tuns or vats within a given period. It may be likewise stated that, with the view of giving a purer whiteness to the product, it is submitted, either in vats or in close chambers, to the action of chlorine or of sulphurous acid, either dissolved in water or as gases. By a slight elevation of the temperature in the primary stages of the hot-water desiccation, the starch undergoes a change which causes it to dissolve in water at a lower heat than it otherwise would; the product so heated bears the name of *soluble starch*.

STARCH FROM POTATOES.—For a long time the manufacture of starch or fecula from potatoes has been rapidly extending in France, and has now assumed so much importance that it ranks, in money value, next to beet-root sugar. In England the practice is not so general, and its development has been much checked by the potato disease. It has been already shown that this esculent yields a large quantity of starch, and the product so obtained possesses all the qualities adapted for ordinary application in calico printing, &c. *cetera*; it is also extensively mixed with farina, for increasing its whiteness; it is employed in the confection of vermicelli, semolá, tapioca, polenta, and a number of other alimentary substances, distinguished by various designations; also in the formation of dextrin or artificial gum, grape sugar, sirups, molasses, wine, beer, alcohol, vinegar, and several other uses.

In large potato-starch factories it is necessary to have considerable storage room for retaining the tubers during the most part of the year; and care must be taken to obviate, as far as possible, the conditions under which the starch in the potato is liable to undergo alteration. Thus all affected or diseased potatoes should be carefully removed from those which are sound, and the latter ought to be kept in a dry atmosphere, and at a temperature as low as possible. Dry cellars or pits formed in the ordinary way, if dry at the base, and securely covered with straw and earth, serve for some time; but a well-ventilated barn or shed with grated floorings, one over another, whereon the potatoes may be laid to the depth of two feet, or thereabouts, will answer the end much better. In any case it is necessary that, during the spring and first of the summer months, the potatoes be turned frequently, so that any shoots which may be forming be broken, and the progress of decomposition in the substance of the bulbs be thereby intercepted.

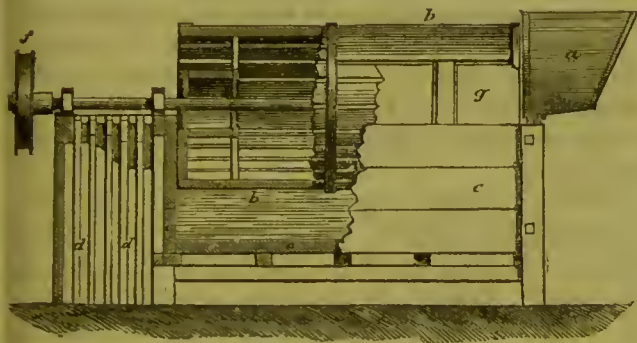
Few operations are simpler than the extraction of fecula from potatoes; nothing further is necessary than the rupture of its cellular matter either by rasping or grating, so as to liberate the starch granules, and the washing of this pulp upon a metallic plate or stage by a stream of water, such washings being afterwards passed through a fine sieve. The solid matter of the potato is thus left on the plate, whilst the starch is carried off in the water, and separated from any grosser impurities by the straining or sifting.

Finally, the fecula is purified by washing and decantation, *et cetera*. Simple as this process may appear, it is divided into several distinct operations, which will be described in the order in which they are carried on in the French and other manufactories of fecula.

STEEPING THE POTATOES.—This operation, which is preliminary to the washing, and has in view the softening of the clay and other adhering gross matter, that they may be more easily removed, is performed in a large trough or vat, filled with water, in which the potatoes are allowed to steep during six to twelve hours, according to the quantity of the impurities.

THE WASHING.—The next operation is the washing

Fig. 546

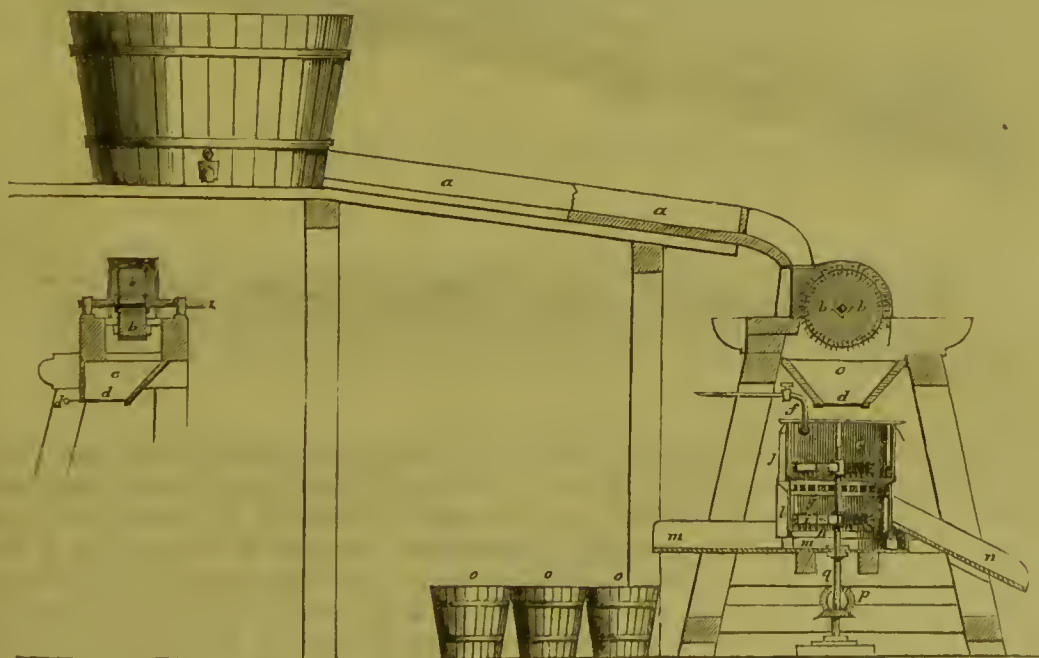


which is effected by mechanical means and the aid of steam. Fig. 546, represents an elevated view of the machine employed, which consists of a hollow cylinder, *b b*, constructed of laths of wood or iron,

laid longitudinally from one end to the other, the distance between each being such as to permit of the escape of the dirt, stones, *et cetera*, whilst the tubers are retained. The cylinder is charged from a hopper, *a*, at one end, and being slightly inclined, the washed potatoes are discharged at the opposite end, down the inclined plane, *d d*. About a third of the cylinder is immersed in the water of the trough, *c c*, wherein it revolves, and from the sides of which spring the boards, *g g*, slanting to the upper part of the cylinder, and intended to prevent the splashing of the water during the movement of the machine. This cylinder is worked by a band passing over the wheel, *f*, at the end of the axis, and a drum-head of another shaft in connection with the main shaft of the engine. The inclined plane upon which the potatoes fall when thrown out conducts them to the rasping machine.

RASPING OR GRATING.—The object of the rasping is to reduce the tubers to a pulp, by which the cells containing the fecula are ruptured; and the finer this rasping is effected, the more freedom will the starch have in escaping. In some instances, this operation is performed by means of a hand-machine; but generally, the larger factories adopt a machine by which the rasping and the washing of the pulp are effected consecutively. The circular drum bearing the rasp is turned by a winch handle, and while revolving meets the tubers in the hopper, reducing them to a pulp which falls by the aid of inclined boards into a vessel moving on wheels, and on which it is carried to the washing stage. A small stream of water is conducted on the upper surface of the rasp, with the view of keeping it clean from accumulation of pulp. The rasp itself

Fig. 547.



is made of plate iron, punched from the reverse side with an angular, semicircular, or round tool on a yielding support, which allows the angular fractures of the iron on the under side to remain unflattened. With a machine of this kind, from two and a half to three tons of potatoes can be turned into pulp by three men in twelve hours. The other kind of machine is

shown in Fig. 547, in connection with a portion of the washing apparatus. It consists of a cylinder about twenty inches diameter, and the same in length, mounted upon an axis. The cylinder is armed with steel-saw plates, placed at the distance of little more than three-fourths of an inch apart; the teeth of these saws, which are very small and regular, and placed

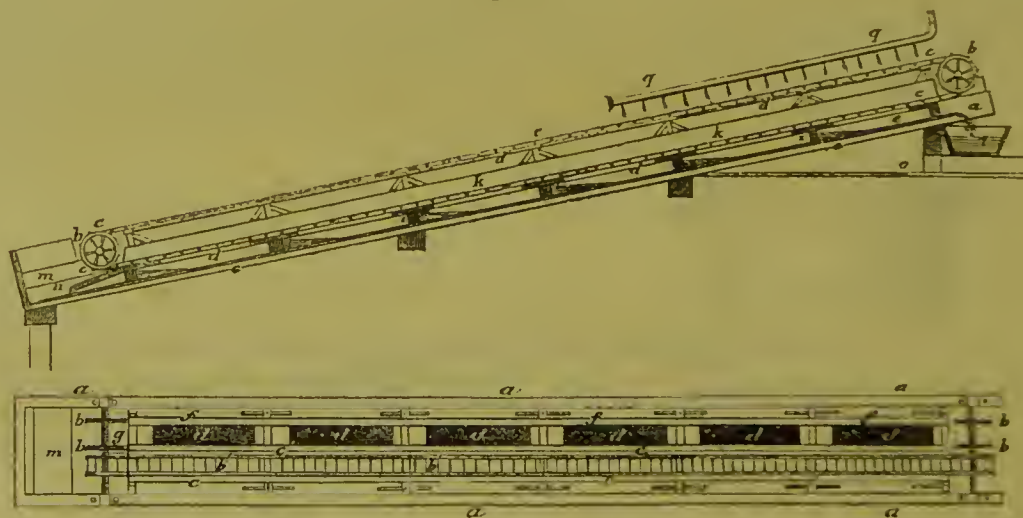
parallel to the cylinder, being held fast by iron clasps, project about four-fifths of an inch from the periphery of the drum, and the whole is turned with a speed of six to nine hundred revolutions per minute. Such a machine, making on an average eight hundred revolutions per minute, reduces to a pulp from sixteen to eighteen heetolitres of potatoes per hour, or forty-two and a half to forty-eight bushels.

In the preceding figure, the rasping drum is shown at *bb*; the inclined plane conveying the potatoes from the washing machine is indicated by *a a*, and the hopper into which the pulp falls by *c*, whence it is dropped into the washing machine by the trap-door *d*. The washing apparatus for exhausting the pulp, is that introduced by M. SAINT ETIENNE; it consists of a cylinder of wire gauze, *e*, fastened upon wooden or iron rings for support, and divided into two compartments, *j*, *l*, each provided with a wirecloth bottom, the lower finer than the upper one. The whole is inclosed in a sheet-iron or wooden covering, which prevents the escape of starchy waters from it when working. In the middle of the cylinder is a shaft, *g*, carrying arms furnished with brushes, *i*, *i*, which sweep the bottom disc of each compartment, and force out the fecula into a trough as the shaft is turned by the gearing of another one, *p*, acting upon a wheel appended to it at its base. By the very rapid

revolution of the brushes and agitators in the drum, aided by the stream of water projected from the rose-pipe, *f*, the pulp is speedily washed, the fecula passing out at the sides and middle disc, *g g*, whilst the coarser pulp is thrown out by lateral openings, and is removed from the outer case by a door into the canal, *n*. The finer portions of the pulp, which pass through the upper part of the machine, are separated in the lower one; the granules of fecula falling through the fine meshes of the wire swept by the brushes into a trough, *m*, leading to the vats, *o o o*, where the starch is permitted to deposit, whilst the fibrous matter is ejected by an aperture at the side, and removed through a door in the case to the canal, *n*. In this form of machine there are several imperfections, which are obviated by a modification introduced by LAINÉ. The principal defects are, that the working is not continuous, the machine having to be stopped at intervals to remove the exhausted residue; that only comparatively small portions can be operated upon at once; and lastly, that the residue is not thoroughly divested of its fecula.

In the machine, improved by LAINÉ, and further perfected by DAILLY, the wire sieves are retained, but the washing space is considerably extended and prolonged, though the quantity of pulp exhausted in a given time is increased. This is done by

Fig. 548.

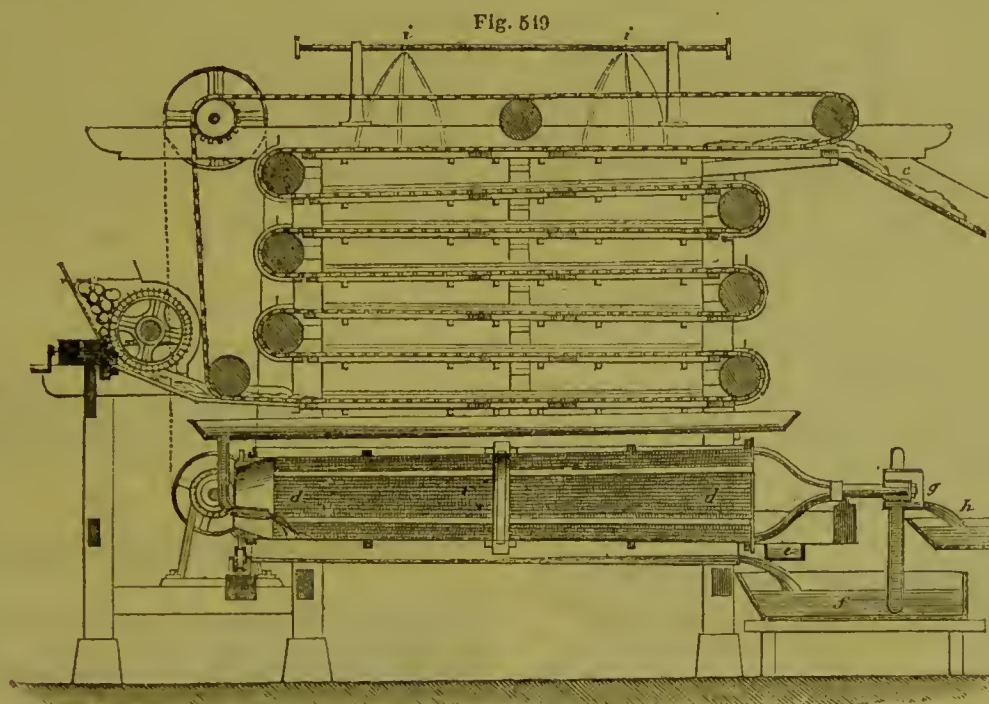


means of an inclined sieve, represented in plan and section—Fig. 548; a long inclined plane is constructed of planks, and this plane is converted into a kind of trough, by side planks, *a a*, secured in their places by cross planks, *i i*, and bolts, which fasten the latter to the base, *e e e*, of the plane. At each end are pulleys, *b b*, the crowns of which are notched in eight places, and into which the bars, *b' b'*, connecting the endless VAUCANSON chain, *c c c*, are caught and carried forward as the pulleys turn. Motion is given to these by connecting the axle of the lower one with the shaft of a steam-engine, water-wheel, or other motive power. Each of the eight divisions of the base of the inclined shallow sluice formed by the cross bars *i i i*, is covered with

a wire gauze, *d d*, increasing in fineness from the lower to the top one; and upon this finely-perforated surface the pulp to be washed is conveyed by the bars, *b' b'*, connecting both links of the chain as it travels from the lower to the upper end, in the slides at the sides and overhead, as seen at *f f f* in the figure. The chain and grooved slides on which it moves on its return overhead are supported by upright pieces of wood, bearing horizontal pieces, *g g*, on which the part *f f f* rests. From the rasping cylinder, or *cylinder devorateur*, as it is called, the pulp is conducted into the trough, *m*; and being diluted with the water employed to keep the cylinder clean, it overflows the inclined board, *n*, and so comes within reach of the cross-bars of the VAUCANSON'S chain as it travels over the lower

pulley, whence it is conveyed over the several compartments of the wire gauze in the inclined plane; but whilst in the act of passing upwards it meets with a stream of water projected from a pipe, *q*, along the upper three divisions of the plane, and which flowing downwards over the several frames, completely exhausts the pulp of all its fecula, leaving nothing but fibrous matter, epidermis, *et cetera*, when it reaches the top and is thrown out into the trough, *l*. From the three upper compartments the water projected upon the mass is conveyed to the lower ones in succession by a series of pipes, not shown in the drawing, connecting the several levels; thus from the lowest part of the highest square, a pipe issuing at the side conveys the liquor to the highest part of the third square; another from the lowest part of the second delivers the starchy liquid of this upon the fourth square, to meet the

ascending pulp; the third sends its water to the fifth, and so on to the lowest and first division, whence it issues into the canal, *r*, leading to the settlers. Two sieves and two travelling chains are generally worked upon the plane, provisions for which are shown in the drawing, the one movement working both. To avoid the inconvenience of the great length to which these planes extend on LAINÉ's plan, and also in DAILLY's, M. SAINT ETIENNE places the sieves one above another, and carries the endless chain over each, as shown in the drawing, by means of pulleys at the ends, the pulp being secured by a flange passing over the pulley and chain in each case. The pulp is delivered at once from the grater or *devorateur* to the chain carriage, and carried upwards till it is discharged at the top into the sluice exhausted of its starch. The disposition referred to is shown in Fig. 549, in which the principal



parts are similar to those last described. The water entering upon the top of the apparatus, flows from the highest of the compartments of each of the levels to the lowest, and thence upon the highest of that immediately beneath, and so on till it travels over the whole space to the base, where, loaded with the fecula, it collects in a receptacle, whence it flows by a pipe into a circular drum, *d d*, of very fine iron wire, revolving upon a central axis moved by mechanical power. Any pulp still retained is here separated and ejected into a receptacle, *e*, at the lower end, whilst the starch flows with the water through the gauze into the vat, *f*, and thence, by a *dénaiide* mounted upon the end of the axis of the cylinder, and revolving upon it, it is lifted into a sluice leading to the settlers, which are disposed as represented in Fig. 547.

By such a machine as the preceding, it is stated that the pulp from one hundred and sixty hectolitres—four hundred and forty bushels—of potatoes is exhausted in twelve working hours.

Besides the foregoing, several other inventors have constructed machines in which the advantages of uninterrupted working, combined with complete exhaustion

of the pulp within the smallest space, have been the points aimed at, and such advantages are claimed by HUCK, VERNIER, and STOLZ for their respective machines. All, with the exception of SAINT ETIENNE, have resorted to the cylindrical wire-gauze sifter, as being the one which affords the largest extent of surface in the smallest space. HUCK's machine consists of two wire-gauze cylinders, connected by a brass drum; in the cylinders are inclosed brushes and rousers, as usual, and also two drums, one for supplying pulp and water to the upper, and another in the lower for supplying water only. Both the wire-gauze cylinders and the drums move independently of one another and in opposite directions, the brushes and rousers taking the same course as the inner drums. The continued agitation in passing through both the cylinders, together with the action of the rousers, deprives the pulp of the most part of the fecula. The starchy liquid is collected in a cistern beneath, and flows into a third circular sieve in which only brushes revolve, but the wire of which is much finer, so that the last portions of pulp are separated. VERNIER employs a combination of three cylindrical sieves moving on the same axle; the

pulp arriving at the upper part of the first or smaller cylinder falls into it, and subsequently by the rotation of the entire system, as well as by the inclination at which the cylinders are fixed, it traverses each successively, being always exposed to a stream of water, till the exhausted matter finally issues partially drained from the middle one. The drainings from the sieves collect in a tank below the cylinders, and are thence conducted through another fine cylindrical sieve for depuration before they are run off to the settlers. STOLZ's machine is on the same principle as the preceding, and is said to be very effective, working off not less than four hundred and forty bushels of potatoes in a space of not more than twelve or thirteen feet. Whatever be the form of sieves employed, it is evident that the efficiency of the process depends in a great measure upon the quality of the rasping machine, and the fineness to which it reduces the tubers. On an average, only sixteen to seventeen per cent. of starch is obtained from potatoes really containing from eighteen to twenty or twenty-one per cent.; and therefore from two to four per cent. is left in the residue in consequence of the inefficacy of the *devorateur* to rupture all the cells containing the starch corpuscles. VÖLKER to obviate this, proposed to disintegrate the cells of the potato more completely than is done by the rasping machine, by submitting the pulp to a fermentative process, at a temperature between 68° and 86° in presence of sufficient water, by which the cells are in a short time destroyed, and the whole of the fecula is set free to be removed by a course of sieve washing. Though good in principle, yet the time occupied, and the difficulty of removing the greatly disintegrated cellular substance, offer almost insurmountable obstacles to the adoption of this method.

After the extraction of the starch from the fibrous matter of the pulp, the next operation is the separation of any particles of sand, clay, and other heavy impurities from the fecula. This is done by allowing the liquor as it passes off from the sieve to collect and repose for the space of a few hours, when the supernatant liquid is siphoned off, and the deposit agitated with its own bulk of water; the mixture is then passed over a fine sieve, by which stones, sand, and coarser impurities are removed. Three or four such repetitions with fresh water, using at each successive sifting a finer wire gauze than the preceding, complete the purification. To assist in this part of the work a mechanical agitator is employed in the large fecularies, similar to that shown in Fig. 553, and which may be elevated or lowered at pleasure by a lever handle. When such an arrangement is appended to the sieves the labor of purifying the starch is much diminished, as the various impurities are retained in the intermediate vessels.

PURIFICATION.—The several filtrations and depositions above alluded to being effected, the milky liquor is allowed to flow into large settlers, where it is left to repose for several hours, till the whole matter in suspension falls to the bottom; the clear water is then siphoned off, and the brownish layer on the surface, consisting of fibrous particles, pulp, and other substances lighter than the fecula, scraped off as clean as

possible by an iron scraper. This impure starch is agitated with fresh water, and then passed through a very fine brass wire or silk sieve, and allowed to rest for some time, till a further amount of white starch falls, when the same operation is repeated. The deposit left after the removal of the brownish light matter is known in the French and Belgian works as *gras de fécule*. It is further purified by stirring it with fresh water, passing the mixture through a No. 90 brass wire sieve, or one of silk cloth, conveying the milky liquid into a vat, allowing it to rest till the starch falls, then decanting and scraping the surface, and finally, if the mass be pure and of sufficient consistence, dividing it into lumps and placing these to dry, either unsupported or in a conical wire case; if it has not acquired this density it is customary to agitate it, and to run the thick semifluid mass into small perforated boxes lined with coarse cloth, such as flannel or calico.

Sometimes the purification of the fecula, deprived of its supernatant brownish deposit, is effected by washing it under a slight stream of water on an inclined table or sluice, twenty to twenty-four feet long by three feet in breadth, and declining one and a half to two inches in its whole length; the lighter matter is carried off by the water, leaving the pure fecula. Figs. 550 and 551

Fig. 550.

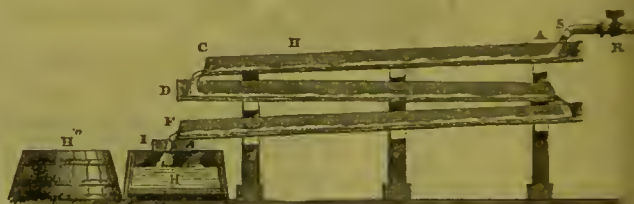


Fig. 551.

illustrate this arrangement; A, C, represent a portion of the first plane; D the next; and F the third; the three being placed on supports one above another to economize room. The starch being spread upon the first ledge, a stream of water in numerous small jets is delivered upon it by the pipe R; the workman agitates the surface of the layer with a brush, and the slight current carries the lighter particles forward, depositing a portion of the fecula in suspension as it proceeds, till it arrives at F, whence it falls into the canal, I, and thence into the settler, II. The purified starch is then brushed from the plane under a stream of water into the second vessel II'; and by siphoning the liquor from the vessel II into II'', the operation of laying a second batch may be proceeded with. As soon as the fecula has subsided in the tub or vat II', the water is decanted; the starch is then transferred into boxes of a conical form, perforated

to allow the water to drain away, and covered with cloth and set aside.

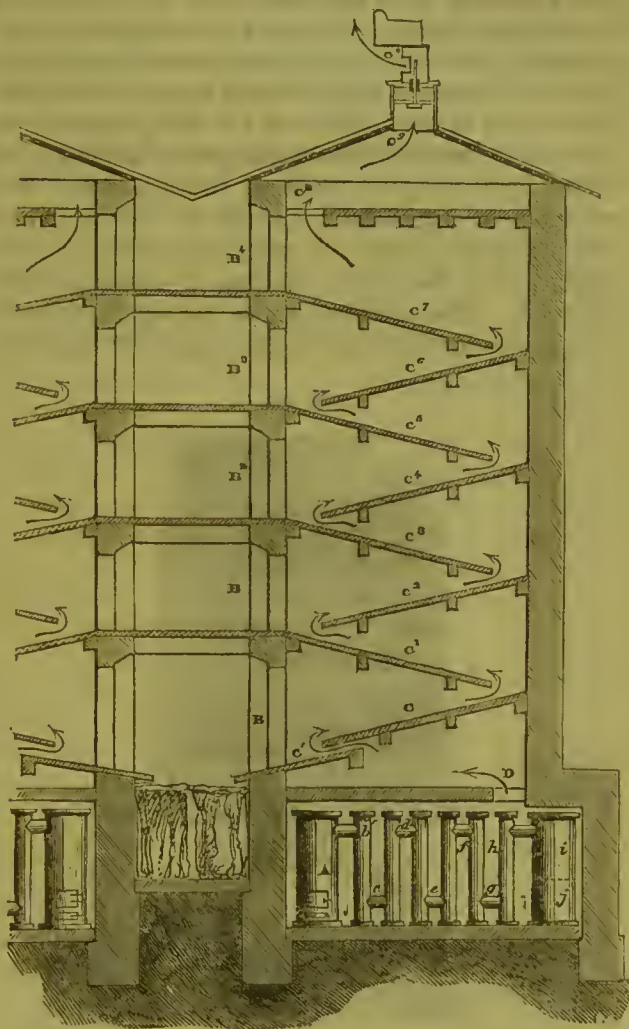
DESICCATION.—At this stage another operation, the *drying of the starch*, commences. It may be remarked here, however, that the large quantity of fecula which is converted into grape sugar and dextrin is not dried, but is at once acted upon in a manner which will be described at the end of this article.

During the time that the starch is allowed to drain in the lined boxes, it acquires sufficient hardness to enable it to retain the shape of the box; and as soon as this state is attained, the mould of starch is inverted upon a mass of plaster of Paris, which abstracts a further portion of the retained moisture, thereby rendering the loaf of fecula so solid as to endure being placed upon the stages of the drying-house for further desiccation. In this state the product is known as *green fecula*, and contains fully two-thirds water.

Desiccation in Free Air.—The free-air drying chamber is a large rectangular room, on either side of which are ranged, one above another, a number of horizontal shelves formed of bars of wood placed at a distance of three quarters of an inch to one inch apart, the whole being supported by upright posts, as shown in Fig. 552. A current of air is passed through the gallery by means of venetian ventilators at both sides, which admit of increasing the draught at will without permitting much dust to enter. The loaves of fecula are broken into three or four pieces, and laid on the longitudinal hurdle or bars already mentioned, on which they are permitted to remain during six or eight weeks; they are then taken, and, if necessary, reduced to powder under a wooden roller, and placed in the hot-air stove. In the construction of the latter, it is indispensable to have the arrangements such that the heat may be entirely under control; for if a high temperature were to act upon the starch, the corpuscles would be swelled to bursting, and a number of gummy concretions in proportion to the extent of the change would result. Such a consequence need not be feared after the chief part of the water still retained in the starch—amounting to forty per cent.—has evaporated. Several kinds of drying stoves are used for this purpose; one being a long gallery like the preceding free-air drying chamber, closed with apertures in the front for sliding shelves, on which the starch is placed to pass inwards where the warm air circulates. The heat in these cases is obtained from cast-iron pipes passing round the walls at the base, in which the draught from a fire is conducted to the chimney; and getting thereby warm they heat the air in the interior as it passes through the compartment. Fig. 552 is a sectional view of the drying stove of LACAMBRE and PERSAC, in which the starch is exposed gradually from 60° to 212°, the highest degree of heat to which the fecula is subjected. It consists of a chamber, beneath the ground floor of which a heating apparatus consisting of a stove, A, and a system of iron pipes, b, c, d, e, f, g, h, i, leading to a chimney, is erected; and the air entering this compartment by lateral apertures passing over the heated surface of these pipes gets warmed and ascends by the opening, D, in the drying chamber, where, following the direction of the arrows, it suc-

cively passes over the inclined tables, c, c¹, c², c³, c⁴, to c⁷, and thence to the outlets—c⁹ and c¹⁰—at the top. The starch passes in an opposite direction, being intro-

Fig. 552.



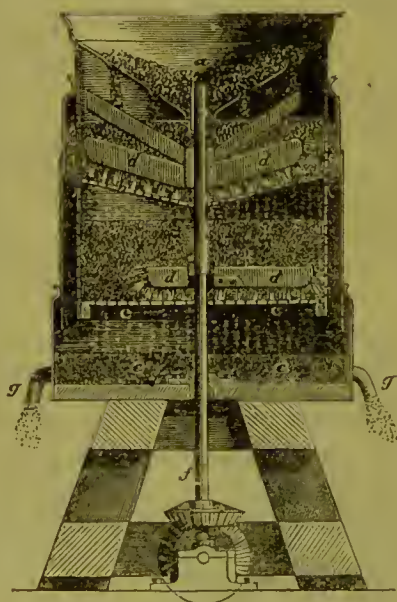
duced at the door, B⁴, at the top upon the plate, c⁷, and thence it is pushed forward over the plates, c⁶, c⁵, c⁴, c³, by the aid of the working doors, B³, B², B¹, and B, till it arrives dried at c, and falls upon the ledge, c¹, into the receiver outside the wall of the chamber.

Another drying chamber constructed upon the same principle, but self-acting, consists of a chamber and heating apparatus essentially like that last described; but instead of plates inclined one towards another, there are a number of rollers fixed two and two at the same height in the interior, upon which travels an endless band of cloth, and which are sustained in the middle by cross rods of wood. By means of gearing-wheels on the ends of these rollers, the cloth of each pair is moved in an opposite direction to that immediately above it, and the whole are set in motion by the power acting upon the highest roller, c, in the chamber. All the gearing-wheels on the axles of these rollers being of the same diameter, they move with the same velocity, so that the moist starch, introduced through the door at the top and spread upon the web, is carried forward from one end of each web to the other, till it reaches the utmost limit of the lowest one. From the disposition of the rollers the fecula falls from one

cloth to another alternately at either end, and ultimately into the chamber, the heated air ascending in an opposite direction.

The fecula during the passage through these hot-air chambers loses from eight to fifteen per cent. of moisture, according as it has been more or less dried in the free-air chamber, and is now in the ordinary state for sending into the market, except when, for laundry purposes, it is mixed with a certain amount of coloring matter, such as smalt blue and the like, or sometimes of late with incombustible matters, to secure fine light dresses from being so prone to ignition. Fig. 553 represents an apparatus employed for this purpose; *a* is a conical hopper in which the fecula is put, together with the smalt, indigo, or Prussian blue employed. The mixture passes through numerous holes in this funnel-shaped hopper, and falls upon the

Fig. 553.



first sifter, *b b*, through which it is urged by the revolving brushes, *d*; thence it descends to the second and finer sifter, *c c*, swept, like the other, by brushes, which accelerate the passage of the fecula into the bottom, *e*, of the vessel, and from this it runs by the tubes, *g g*, into sacks or boxes placed for its reception. The brushes are attached to a central shaft, *f*, which is turned by the gearing-wheels in connection with an engine, or other motive power. Sometimes the slight coloration which is given to laundry starch, as sold by grocers generally, is communicated immediately after the first desiccation in the free-air chamber; and the moisture is driven off afterwards in the drying stove.

RICE STARCH.—Within the last twenty years the extraction of starch from rice has received considerable attention in England; and is now extensively practised. It will be seen from the results stated at page 950, that this grain contains more starch in proportion to its other constituents than any other; the gluten, however, is so minutely divided in it that its separation was impossible by the old system of fermentation, and this accounts for the preference so long given to wheat and flour. By the partial use of chemical agents

this difficulty has been overcome, and rice is now extensively employed for the manufacture of starch. Among the several patent processes introduced for this purpose are those of JONES, BERGER, BURLY, REHE, and others, who employ either an alkali or an acid for the solution of the gluten.

JONES directs that the rice be steeped in a solution of caustic potassa or soda, containing two hundred grains of alkali to the gallon, using fifty gallons of solution to one hundred pounds of rice; the mixture is well stirred, and then allowed to digest for twenty-four hours; after which the liquor is siphoned off as much as possible, and the grain is washed with twice as much pure water as the liquor drawn over. The grain is then placed upon a drainer, after which it is crushed or ground between stones or rollers, and the coarse flour sifted in an apparatus furnished with brushes. That which refuses to pass through is returned to the mill with a fresh portion of prepared grain, and the process is repeated until the whole, with the exception of the husk, is made to pass through the sieve. The meal thus obtained is treated with a further quantity of the alkaline liquid, the proportions being one hundred gallons to a hundred pounds of the meal, and the action is quickened by frequent agitation of the mass during twenty-four hours; after which it is allowed to repose seventy hours. During this period there is first a deposit of fibrous matter with a little starch; then the starch falls, the chief portion of the gluten, with some other bodies, being retained in solution by the liquor, which is removed by a siphon without disturbing the separated matter. Double the previous quantity of pure water is now poured on the starch, the whole being well agitated, and allowed to rest for an hour, to permit the heavy substances other than starch to fall to the bottom; this done, the milky liquor containing the chief portion of the pure material is drawn over into another vessel, being passed in its course through wire or cloth sieves. A further quantity of water is used to wash the deposited matter, which, being agitated with the liquor as before, the whole is left to rest; and after the crude impurities have fallen, the starchy menstruum is again drawn off. By repeating these operations as often as may be necessary, the separation of the starch is completed; and the fine silk or brass-wire sieves detain any fragments of husk, so that the substance is well purified. All the successive liquors being added to the first, the whole is stirred and then left to settle for seventy hours; after this time if the whole of the starch has subsided, the clear supernatant liquor is drawn off, the deposit is mixed with the necessary quantity of coloring matter, and then treated in the usual way by boxing, draining, and desiccating.

BERGER's process is analogous to that just described; a hundredweight of the rice is steeped during two days, then removed from the water, and after being drained, is crushed or ground to meal, among which as much water is introduced as to give it the consistency of thick cream; in this condition it is passed through a sixty-holed sieve, returning what is too coarse to be further ground. The filtered or sifted mass is now stirred with a solution of seven pounds and a half of carbonate of soda in three and a half

gallons of water; and when the whole has been thoroughly blended, it is allowed to rest during four hours, then agitated again, and the operation repeated at equal intervals till the contact has been prolonged to about sixty hours. After this it is suffered to rest eighteen hours, and at the end of that time the lie containing the chief portion of the albumen is drawn off. A second treatment with a similar lie is succeeded by a washing with large quantities of water, and after allowing the heavy particles to fall, the milky liquor is passed through fine sieves, and the starch further purified by the inclined plane, or by repeated washings and depositions.

By another process, likewise patented, BERGER proposed to prepare the starch of rice by fermentation, the chief feature of which is the steeping of the grain in water for successive periods of four to six days, then grinding in the usual way, and repeating the steeping until the entire gluten has been so far altered by fermentation as to be taken up by the several liquors; the starch is afterwards finished by siftings, washings, *et cetera*.

COLEMAN, in 1841, patented the following method of preparing rice starch by fermentation:—The rice is steeped during five or six days, then drained from the water, and ground in the usual way; the meal reduced to a pulp is mixed in the recipient with a quantity of the refuse of wheat, or other fibrous matter, in the proportion of fifteen pounds of the latter to the hundredweight of rice, and a sufficient quantity of water is added to reduce the whole to a homogeneous mass, which is allowed to rest during ten to fifteen days. The patentee states that by this time the starch will have separated, and may be purified in the ordinary way by washing and sifting.

Another mode for preparing rice starch by the agency of acids is thus described:—The substance after being steeped for four days is drained, and then reduced to a pulp in a mill under a stream of water, which carries it off to a reservoir, where it is allowed to settle, and the water is then separated by a siphon or plug-hole in the vessel. The deposit is then agitated with an acid liquor prepared by adding three quarters or one ounce of ordinary hydrochloric acid with two pounds of rice to the gallon, stirring well the whole mass, and leaving it to stand during five days with agitation at intervals of four hours; finally, eighteen hours are allowed for the substance to deposit, after which time the clear liquor is drawn off, and the operation repeated with a second acid liquor three-fourths of the strength of that first used. When the period mentioned for the final deposition of the starchy mass has transpired, the acid liquor is drawn off as before, and the residue washed with large quantities of water, passing it through sieves as usual to separate the husk and other impurities which may still remain, and finally the mass is drained and dried in the ordinary way.

RENE took out another patent for a method for preparing rice starch, the chief feature of which is, that he submits the rice at first to a temperature of 160° to 180° before steeping; and after the matter is levigated, he employs a stronger alkaline lie—four pounds of soda to a hundredweight of rice—for washing the pulp.

In the subsequent washings, *et cetera*, the treatment prescribed by the patentee is similar to those already mentioned.

RAINSFORD employs hydraulic pressure in conjunction with alkali to extract the fibrinous matter from the rice before grinding, and finishes the product by further treatment with alkaline-water washings, siftings, and the like; he uses pressure also to expedite the operation of expelling the last portions of water from the finished starch.

MAIZE OR INDIAN CORN STARCH.—Of late years maize has been used for the manufacture of starch, and has been found to answer the purpose very well, containing as it does a large percentage of that substance. The principal makers are POLSON and BROWN of Paisley, Scotland, who employ a process patented by the former in 1854. By this method the grain is first steeped either in an alkaline water of the usual strength, or in water only, till thoroughly soaked; it is then levigated in the ordinary way either by rollers or a mill, and the pulp is passed over a sieve, through which the finer portions are forced by revolving brushes, whilst the coarse matter is returned to the mill to be further levigated, and is then sifted again. In this way most of the husk is separated from the flour or starchy portion of the grain, and is economized as cattle food. A stream of water passes in upon the sifting machine, and carries the portion passing through the sieves over an inclined plane, or *run*, the breadth and length of which are proportioned to the work to be performed. In its course the heavier starchy matters subside, and the lighter fibrous substances are carried forward by the stream till they are thrown off. The plane is divided by dams, or pieces of wood laid across it, which intercept the deposited starch, until it accumulates in quantities convenient for removal. Most of the glutinous or fibrinous matter and husk is thus separated, and a starch is obtained which, though not entirely free from nitrogenous and fibrous matter, answers well for ordinary coarse work, having high stiffening powers. It has also been introduced by that firm as an article of diet, and meets with extensive patronage. When a finer kind of starch is to be prepared, the deposit from the plane is treated with an alkaline liquid, by which the gluten is dissolved; and by sifting through a finer texture, washing on the plane, and the other usual manipulations, the starch is obtained perfectly pure.

WATT of Belfast is also patentee of a process for preparing starch from maize, and which in its chief features is similar to the foregoing, with the exception that WATT steeps the grain in repeated changes of water, or in a current, till incipient fermentation takes place, the water being in either case heated between 70° and 140°; after which the matter is drained and ground as usual, with the necessary quantity of water, likewise heated, to reduce it to a creamy consistence. This is then sifted with the aid of brushes, and the coarser portions returned, if necessary, to be again levigated, *et cetera*. The sifted matter is washed and purified either by the inclined plane or in vats, as in the preceding methods.

STARCH FROM MILLET.—A process patented by RICKETT for the extraction of starch from millet,

especially from that kind known as *Dari*, embraces the usual series of operations, namely, steeping, grinding, sifting, and treatment with alkalis, alkaline carbonates, or acids, such as hydrochloric or acetic acids, washing and finishing in the manner already detailed.

STARCH FROM HORSE-CHESTNUT.—HEDENUS and FLAUDIN have proposed to extract starch from the horse-chestnut, in which it is stated to be contained to the extent of twenty-five per cent. The chestnuts are steeped in boiling water, then skinned and grated; the pulp well mixed with soda in the proportion of one per cent. of the chestnuts operated upon; and, after a certain time, the starch is obtained by washing the mass in the ordinary way. The alkali, it is said, thoroughly removes the bitter principle of the nut.—*Richardson and Ronalds.*

ARROW-ROOT STARCH.—This starch, so named from its virtue, as formerly supposed, of curing wounds from poisoned arrows, is extracted from the roots of plants of the *Marantaceæ* of LINDLEY, more especially from those of the *Maranta arundinacea* and *M. Indica*, natives both of the East and West Indies. There are also other plants which afford a starch, designated by the same title and the name of the locality of its production. Such is the Portland arrow-root, extracted from the *Arum maculatum* of the order *Aroideæ*; the Brazilian arrow-root, from the *Jatropha manihot* of the order *Euphorbiaceæ*; East Indian arrow-root, from tubers of the *Curcuma angustifolia* of the order *Zingiberaceæ*; and Tahiti arrow-root, or tacca starch, from the roots *Tacca oceanica* of the order *Taccaceæ*, with many others. Arrow-root is a snow-white powder, and is very much prized as a dietary article, though its estimation in this respect has now considerably diminished. The starch which is contained in cells in the joints of the rhizome or underground stem, is extracted in Jamaica, as PEREIRA states, in the following manner:—The tubers, when about ten or twelve months old, are dug up, well washed in water, and then beaten to a pulp in large, deep, wooden mortars; this pulp is thrown into a large tub of clean water, well stirred, the matter strained, the residuary pulp expressed and thrown away. The milky liquid thus obtained is passed through a cloth or hair sieve, allowed to settle, and the clear supernatant liquid drained off. More clean water is poured on the white deposit, the whole stirred; and, after the deposition of the solid matter, it is drawn off as before. Finally, the deposit is drained and dried on sheets in the sun, when it is fit for commerce.

In Bermuda, and in the Island of St. Vincent, the tubers are carefully deprived of their paper-like scale, as this is said to contain a resinous matter which imparts both a color and a disagreeable flavor to the starch; they are then rasped by a machine, or ground by a mill, and the meal being well washed with pure water through various forms of sieves is ultimately dried. To insure greater purity of the product, URE states that the vessels and cylindrical sieves employed on many of the estates, are constructed of tinned copper; that the scrapers used to remove extraneous matter from the deposit, as well as the shovels with

which it is packed in bags, are made of German silver; and that whilst drying, it is protected from dust and insects by a veil of white gauze.

A method similar to that first stated is followed in the East Indies, for extracting the starch from the roots of the same plant, as well as from the *Curcuma angustifolia*, the product of which is distinguished as curcuma starch, or *tikor*, imported from Celebes. There are two varieties of the latter, the white and buff-colored *tikor*, or East India arrow-root, and which can be readily distinguished from the West Indian product, both by its physical properties and by its appearance under the microscope. PEREIRA states that the white *tikor* appears to the eye to resemble finely-powdered salt, such as bicarbonate of soda; that when pinched or pressed by the fingers, it wants the firmness so characteristic of the West Indian arrow-root. The form of the granules under the microscope he states to be different, the curcuma starch being transparent flattened disks of an ovate, or oblong-ovate shape, having a very short neck, or nipple projecting at one extremity where the hilum is situated; and, owing to the flatness of the grains, they have but little lateral shading, except when viewed edgewise. The lines forming only segments of circles. Both these kinds are used for food, like the West Indian product to which, however, they are deemed much inferior. Portland arrow-root, or Portland sago, so named from being imported from the island of that name, is prepared much in the same way as the foregoing, namely, by scraping the tubers of the *Arum maculatum*, pounding or rasping them in a mortar or machine, washing with water, straining, *et cetera*. It is a white amylaceous powder composed of exceedingly small granules of a circular, muller-shaped, or polyhedral form, having a hilum in a central depression in the grain. This article is likewise used as a dietary.

CASSAVA STARCH.—Known also as tapioca meal and Brazilian arrow-root, is obtained from the roots of the *Jatropha manihot*, a native of Brazil. The roots contain a powerful acrid poison which is readily extracted by water and destroyed by heat, so that, in the course of the preparation of the starch—a process similar to those already described—the poison is entirely separated. It is imported into England from Rio Janeiro, and appears as a white pulverulent substance resembling the genuine arrow-root. Under the microscope the difference is seen at once, this starch being somewhat similar to the Portland arrow-root in the shape of the granules, though much smaller; the hilum circular and surrounded with rings.

Tapioca.—This substance is the meal from the roots of the above-mentioned plant, scraped, washed, and rasped into flour. Whilst still moist it is dried upon hot plates, by which treatment some of the starch grains swell to bursting, and the amylaceous matter thus liberated cements the whole into small irregular masses. Hence tapioca is partially soluble in water. In boiling water it swells up and constitutes a transparent jelly-like mass.

Tahiti or Otaheite arrow-root is obtained from the tubers of the *Tacca oceanica* and *pinnatifida*, a native of Tahiti and other South Sea islands. It is imported

into London, and sold under the title of *arrow-root prepared by the native converts at the missionary stations in the South Sea islands*. The tuberous roots, which yield a highly nutritious fecula, are washed and scraped to remove the outer skin, then reduced to a pulp by rubbing on a kind of rasp made by wrapping coarse twine from the cocoa-nut fibre tightly round a board, or, as ELLIS states, on a piece of coral; the pulp is then washed with sea-water on a sieve made of the fibrous web that protects the young frond of the cocoa-nut palm. After the deposition of the fecula the liquor is drained off, the sediment made into balls and dried in the sun from twelve to twenty-four hours, then broken up, and the desiccation finished in the sun. This starch has a slight musty odor, though in color it resembles genuine arrow-root. Its particles appear smaller than cassava starch; they are circular, muller-shaped, and polyhedral, having a small circular hilum, and but few and not very distinct rings.

There are a great many other tropical plants from which starch could be extracted, such as the unripe fruit of the plantain and banana, and the tuber of the *dioscorea* or yam, the former of which is stated to afford seventeen per cent. of starch, and the latter nearly twenty-three per cent.

Tous-les-mois.—The starch or fecula bearing this name is allied to the preceding. It is extracted from the tubers of the *Canna edulis*, a native of the West Indies. The seat of its manufacture is principally St. Kitts, whence it was introduced into England in 1836. From the account of Mr. WORDSWORTH, it appears that the plant grows to the height of four feet or more, and yields a tuber three or four times as large as average-sized potatoes. The fecula is extracted to the amount of twelve and a half per cent. of the tubers by rasping and subsequent washings in the ordinary way. Its granules are much larger than any other kind of starch, not excepting that of the potato; and consequently it may be readily distinguished from the latter by the practised microscopist. In bulk it has a satiny, glistening appearance, somewhat resembling potato starch, but devoid of the dead white of the genuine arrow-root.

PEREIRA gives the following as the principal distinguishing characteristics of this and potato fecula:—

1. The particles of potato starch are smaller and more irregular in size than those of *tous-les-mois*.
2. The larger particles of potato starch are more irregular in shape than those of *tous-les-mois*: the latter are more constantly rounded-oblong, or ovate-oblong; the former more oval, often approximating to the shape of an oyster or muscle shell, or a triangle with rounded corners, and frequently gibbous or tumid at different parts of their surface.
3. The rings seen on particles of *tous-les-mois* are fine, regular, uniform, concentric, and crowded; those of potato starch are coarser, irregular, often eccentric, irregularly drawn out, distorted, or more and unequally distant from each other. In potato starch a greater number of complete rings are visible, and may be traced round the hilum even in case of many of the larger rings. With *tous-les-mois* only a few of the smaller rings can be thus distinguished.

4. The hilum is situated nearer to the end of the corpuscle in the *tous-les-mois* than that of fecula.

Lastly, When viewed with polarized light the cross is generally less regular in the potato starch grains than in those of the *tous-les-mois*.—*Pereira*.

SAGO.—This is the title of a starch extracted from several varieties of palms very common in Sumatra, Borneo, and other islands of the Indian Archipelago; the word is derived from the Malay name, *sagu*, for the palm and the farina itself. The genuine sago is imported into England from Singapore in large quantities, but a fictitious kind is made at home in many of the starch manufactories from fecula and wheat starch. The real plant which affords the sago is still undefined, for several of the species are known to yield it, those of the *Sagus* and *Sagurus* being the most important. The *Sagus rumphii*, *Sagus inermis*, *Metroxylon sagu*—the *rambija* of the Malays—*Corijota urens*, or sago palm of Assam, *Borassus gomuto*, and a few others are the most resorted to, together with several species of *Zamia*, *Corypha*, and *Mauritia*. In most of these trees the pith is so abundant as to constitute a great part of the bulk of the entire stem, which from its rapid growth often attains to a thickness of a foot or more in diameter in the course of six or seven years. From such a tree it is stated that as much as three hundred-weight of sago can be obtained.

The method adopted for extracting the medullary matter from the tree and separating the starch from it is somewhat different from that followed in preparing arrow-root starch; but the mode of preparing the sago bears so much resemblance to the European system of preparing grain starch, that it will be unnecessary to enlarge upon it in detail. In the Moluccas, the tree when sufficiently matured is cut down near the root, and then divided into portions averaging seven or eight feet in length, which are split open and the pith extracted. By various means—such as pounding in a mortar, *et cetera*—this substance is reduced to a coarse powder, which is agitated with water and submitted to the usual siftings and washings; the farina is then allowed to deposit, and on drawing off the fluid and drying the residue, the *raw sago meal* is obtained. From this the granulated and pearl sago is prepared, after submitting it to a bleaching process preparatory to granulation. To bleach it, the sago meal or flour, mixed with water to the consistence of cream, is exposed in close vessels to the agency of sulphurous acid or chlorine, or to a solution of hypochlorite of lime or soda, and afterwards well washed; a little sulphuric acid being mixed with the washing water when the hypochlorite is used.

In New Guinea the granulation is performed by making a paste of the sago meal with water, and passing this through a sieve into a very shallow iron pot placed over a fire. The particles on being heated assume a globular form. BLUME states that the same method is followed in Singapore by the Chinese, only that during the heating the particles are constantly stirred and turned; he adds, that though the material is quite white at the commencement, it gets hard and somewhat pellucid during the process. PEREIRA says that the tapioca sago of GUIBORT is submitted to the

action of heat, but so well managed is the operation, that none of the substance is in the least charred. He adds that some of the sago of the shops presents no appearance of having been heated, and in this case it is supposed that the granulation is effected by a mill. Two kinds of granulated sago are known in commerce—the common brown or red, and the white or pearl sago. The color is attributed by PLANCHE to the red matter contained in the variety of palms from which the starch is extracted, and by the application of the heat required for granulation altered to a grey, which is the usual color of unrefined sago. Formerly the imported article presented a great inequality of aggregation, varying from very small grains to that of pearl barley or peas, the substance being, however, identical in both, and evidently composed of cemented particles of sago meal. Pearl sago dates from a recent period; CRAUFORD, whose account of it was the first published, states that the method of manufacturing it was discovered by the Chinese of Malacca, a few years previous to 1820, the year in which he wrote. It is met with in pearl-like grains of an irregularly globular form, ranging from the size of a poppy to that of white mustard seed or a little larger. The surface of the larger grains is generally smooth and even, but that of the smaller kinds is uneven and somewhat tuberculated. Under the microscope, the particles of this variety present the same appearance as that of the colored product and sago meal, except that the most of them appear ruptured from the action of the heat. Sago when granulated possesses the property of considerably swelling in hot water or other liquids, without losing its adhesive power; hence the grains appear translucent and gelatinous, but not as slimy globules. The following table by PLANCHE exhibits the quantity of water which the different varieties of sago met with in commerce take up in softening, as also the chief distinctions of the farina itself:—

Source.	Color.	Water absorbed in softening. Per cent.
Maldines,....	Grains, mostly red, some white,..	150
Sumatra,....	Grains, white or dirty-white,....	134
New Guinea,....	Grains, brick-red or lighter,....	121
Moluccas,....	Red variety,	130
Do.,	Grey,	109
Do.,	White,	164

Of late years, more especially in Germany and France, considerable quantities of artificial or fictitious sago have been manufactured from inferior starches, such as *secula*. The process is simple, consisting merely of submitting the starch after air-drying to a temperature of 212° on iron plates, and thus causing the granules to swell to such a degree that some of them burst, when the gummy matter forms a cement that envelopes other granules. Care must be taken that the heat does not rise so high as to discolor the matter by partial charring, which would be highly detrimental. After the heating the mass is passed through a mill, or sifting and rolling machine, by which it is reduced to the globular form of pearl sago. When dry wheat or potato starches are operated upon, a previous moistening is necessary in order to incorporate as much water as will facilitate the swelling and fracturing of the granules at the comparatively low heat necessary to insure its cementation.

DERIVATIVE PRODUCTS FROM STARCH.—The products are obtained from starch which are very extensively employed, not only by themselves, but also for the production of other substances of considerable importance. These are *dextrin* and *glucose*, of which it will be necessary to give a short account.

Dextrin.—This substance has been briefly described under the term BRITISH GUM in Vol. II., page 313, but its importance deserves that some further details should be given here. It is a substance immediately produced from, and isomeric with starch, and is obtained from its property of diverting to the right a ray of polarized light transmitted through its solution. It is soluble in water and in dilute spirit of wine, but insoluble in absolute alcohol. A solution of iodine does not alter its color in solution, except when the transformation of the starch is incomplete, in which case it produces a violet, shading off to a red tint. When the colorless solution of this substance in hot or cold water is evaporated, a viscous mass is obtained, which, on being dried, yields the dextrin in a mass somewhat resembling gum-arabic; it is similar also in its properties, so much so that in many applications it is substituted for gum-arabic at a great saving; and hence the trade that has sprung up of late years in this substance under the title of British gum, *liocom*, *et cetera*. It does not, however, like gum-arabic, yield derivatives, such as mucic acid and the like, when treated with nitric acid and other agents, and in this respect a marked chemical distinction is established between the two substances. On the methods resorted to for its preparation, the Editor has nothing to add to the details given at the page above referred to.

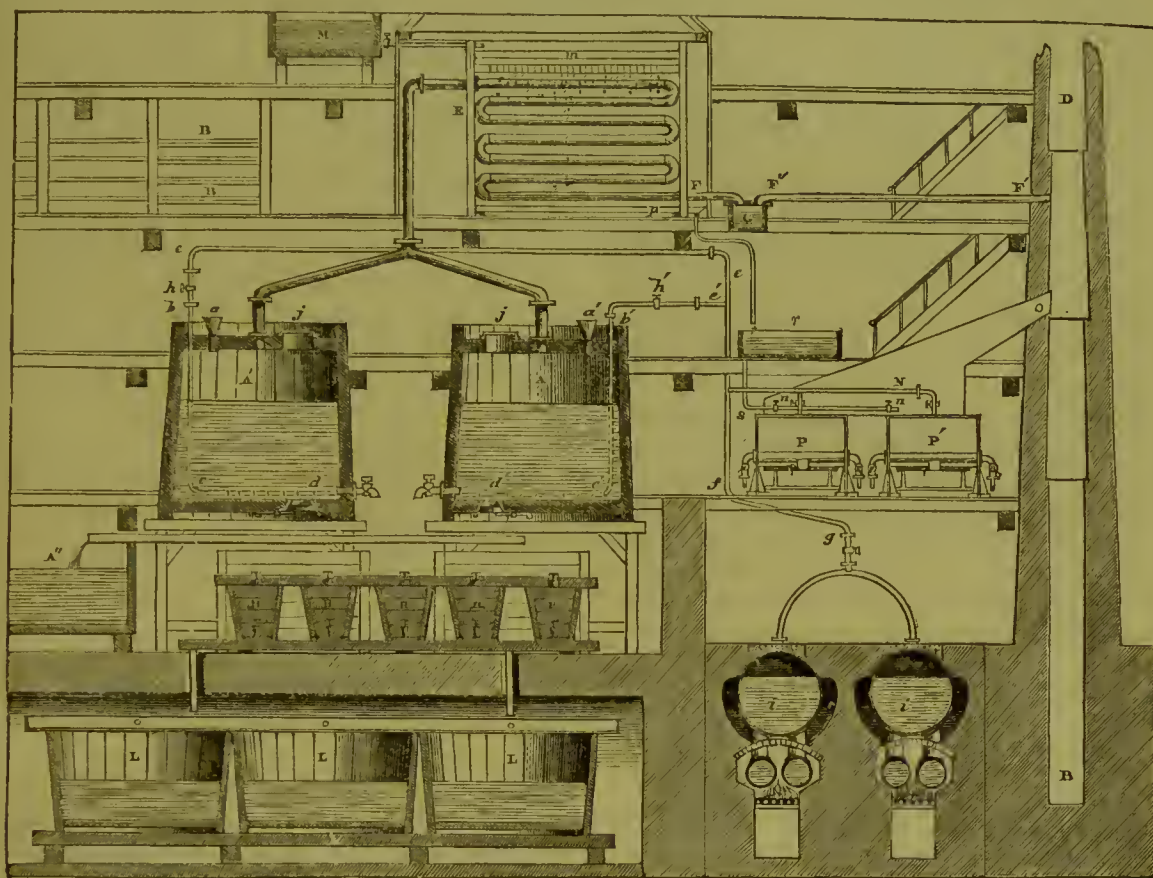
Glucose.—In starch factories, especially on the Continent, a considerable quantity of starch or potato *secula* is converted into glucose—a species of sugar which is found in many kinds of fruit, especially the grape, and into which all other varieties of sugar, whether it be the product of the cane, maple, or beet, is readily resolved by the action of acids and other chemical agents. The chief use to which glucose is applied on the Continent is for the manufacture of beer, and a coarse kind of alcohol, which is said to be extensively converted into French brandy by the addition of oil of raisins, coloring matter, *et cetera*. There are two methods by which the starch, or rather dextrin, is converted into glucose; the one is well exemplified in all the breweries and distilleries of the kingdom, where thousands of tons are annually formed in the preliminary stages of mashing and mashing; the other consists in the use of sulphuric acid, which is a more expeditious method, and gives a purer product than when the conversion is effected by means of diastase. The process is naturally divided into six stages, namely, the conversion of the starch into dextrin, the saccharification of the dextrin, the settling of the liquid, the evaporation, the filtration, and the concentration. PAYEN describes the apparatus and operations connected with it as follows:—

The saccharification of the starch is effected in large tubs or vats, A A'—Fig. 553—constructed of stout wood, to contain two thousand eight hundred gallons. In one of these, A', a lead pipe, *b c d*, coiled at the bottom, is placed, the circular portion being cut or

perforated for the introduction of steam to heat the acidulous water with which it is two-thirds filled; the steam from the generator, *i*, is admitted to it at plea-

sure by means of the pipe, *b f e g*, and stopcock, *h*. During the operation the vat is covered, and the disengaged vapor conducted to the chimney, *B D*; but

Fig. 533.



before escaping it may be utilized in evaporating the sirup by conveying it through serpentine pipes, *E, F*. By such arrangements the disagreeable odors resulting from the evaporation of the oil of the starch are considerably abated, being partly condensed in the serpentine pipe, so as to flow off with the water produced from the steam into a vessel interposed between the pipes, *F, G*, and partly carried away by the pipe, *F', F''*; or the uncondensed vapors may be conducted into the fire where any remaining traces of essential oil are consumed, and thereby the nuisance is almost entirely prevented.

When it is proposed to convert two tons of fecula in such an apparatus, the substance is suspended in portions of two hundredweight in a trough or tub, with twenty-two gallons of water, and when thoroughly steeped, it is introduced by a funnel, *a*, in quantities of four to five gallons at a time, into the large tub or vat, which should be previously charged with about thirty-two barrels of water, and three quarters of a hundred of sulphuric acid agitated with it, the whole being raised to 212° by forcing steam into it. This temperature is maintained till all the fecula is introduced, and it is found that the transformation is accomplished in thirty or forty minutes after the last portion of the starch has been added. The point at which the change is completed is easily ascertained by simply testing a few drops of the clear liquid with a drop of a solution of iodine, when, if the saccharification be effected, no coloration takes place; in the contrary case the cha-

raacteristic violet of iodide of starch manifests itself. After the conversion into glucose, the introduction of the steam is suspended, and the next operation is the saturation of the free acid by means of carbonate of lime, and the consequent precipitation of sulphate of lime. The latter being but sparingly soluble, most of it falls to the bottom. It requires from ninety to a hundred pounds of chalk to saturate the whole of the free acid; and this must be introduced gradually to guard against the evolution of too much carbonic acid at once. If an excess of lime be used, it prevents the solution from clarifying so readily as when the sulphuric acid is barely taken up; this is shown by the cessation of effervescence, and the inability of the liquid to change the blue color of litmus to more than a feeble purple tint. When the saturation is completed, the mixture is either permitted to repose in the same vessel, or if it be required to operate upon another batch at once, it is drawn off into the lower vat *A''*, where it is left at rest during twelve hours; the clear liquid is then racked through coarse bone black in the filters, *H, H*, the deposit of sulphate of lime being also thrown upon cloth filters, where it is drained and washed. The sirup as it flows off from the filter, having a density of 1.11 to 1.122, is retained in the reservoirs, *L, L, L*, from which it is raised by a pump or a chain of buckets to the reservoir *M*; from this it is distributed in a horizontal channel, *m*, by numerous lateral apertures upon the serpentine evaporator, *E F*, and then flows by a channel, *p*, and tube, *q*, into

a receiver, *r*, whence it can be drawn at will by the tube, *s*, and stopcocks, *n*, *n*, into the boilers, *p*, *p'*, which are heated by steam, and in which the liquid is concentrated to 1.26 specific gravity. The sirup thus obtained, after reposing a sufficient time to allow the sulphate of lime precipitated by the evaporation to subside, is fit for the brewer or distiller; but if intended for the confectioner or liquer-maker it should be allowed to rest for twenty-four hours, filtered when cold through coarse bone black, and casked immediately. When it is desired to obtain the glucose in a solid state, the evaporation is carried so far as to concentrate the sirup to 1.38 or 1.39 specific gravity—73° to 74° Twaddell; it is then poured into the cooler, where it is left till the crystallization commences, and thence transferred to the tuns in which the solidification is effected.

Of late years, instead of preparing the sugar in an amorphous solid mass, as by the preceding method, it is obtained in grains or regular crystals. The process for converting the starch into sugar is the same as that already described; but care is taken to do it more thoroughly, since any excess of dextrin in the sirup is found to prevent crystallization. After the acid has been neutralized, and the lime salt removed by deposition, *et cetera*, the saccharine liquid is decolorized, and concentrated to 1.300, or 60° Twaddell, in summer; and 1.262 or 53.5° Twaddell, in winter. At these stages it is racked off into large reservoirs where the lime salts settle down; and during this period it is necessary, in order to prevent any fermentation, that the liquid be cooled either by circulation of air or of cold water in a coil placed in the vessel. After thirty-six to forty hours, the sirup, being clarified and cooled to about 65°, is put to crystallize in ordinary tuns furnished with a false bottom placed over the lower one, which is pierced with a number of holes that are stopped with wooden pegs. These tuns are placed on stages along the walls of the room, twelve to fifteen inches above the floor. A sheet of lead, or large canal or sluice, reaches along each range of crystallizing tuns. To avoid the fermentation of the sirup, which in summer often prevents the crystallization, six or seven ounces of sulphurous acid solution are added to the content of each tun. At the end of eight or ten days the crystallization commences and goes on, the crystals depositing in succession. When the bulk of two-thirds of the liquid becomes a mass of crystals, the pegs in the lower bottom are withdrawn, and the still fluid portion is permitted to drain off, the operation being quickened towards the end by tilting two adjoining tuns against one another. The drainings are conducted to the converting tun, where any dextrin the liquor may still contain is saccharified.

The desiccation of the drained sugar was long a work of difficulty, the moisture of the air being sometimes sufficient to convert it again to sirup, which, with the heat of the factory, melted and agglomerated the remaining portion. M. FOUCHARD has obviated these inconveniences by furnishing the tuns or tubs, *R R*, with tables of plaster of Paris, which absorb the portion of the interposed sirup. This very much quickens the desiccation of the crystals, especially in

a current of air heated to 77°, taking care that the granules are not thereby soldered together. There is, however, a certain amount of the crystallized mass which has to be submitted to a second solution, namely, that which is agglomerated on the end of the loaf resting on the plaster; this must be separated, and the sugar extracted from the sulphate of lime, by grinding them between cast-iron cylinders, and dissolving in the ordinary way.—*Poyen*.

Glucose crystallizes in grains formed of a number of lamellar plates radiating from a common centre, and thus forming a kind of bristling spheroid of lamellar points. It has only one-third the sweetening power of cane sugar, whilst it is once and a half less soluble; at 212° it melts in its water of crystallization, which characteristic allows of its recognition when in certain proportions in cane sugar. It may also be detected by the property which glucose possesses of forming definite compounds with alkaline and earthy bases, which compounds suffer decomposition, and become strongly colored brownish, at a temperature between 160° and 212°, which is not the case with cane sugar under like circumstances.

Glucose is composed of $C_{12}H_{12}O_{12} \cdot 2HO$, differing from starch, $C_{12}H_{10}O_{10}$, only by an addition of two equivalents of the elements of water, and two equivalents of the water of crystallization, with which, however, it parts when carefully exsiccated, leaving the compound of the composition $C_{12}H_{12}O_{12}$.

STRONTIUM.—Although less abundantly diffused, it resembles barium both in its chemical and geological relations. Like it strontium is never found native, but only as *carbonate* and *sulphate*. It was first recognized by HOPE in 1792, in the mineral *strontianite*, so called from Strontian in Scotland.

Pure strontium was first made by BUNSEN and MATTHIESSEN in 1855; impure by DAVY in 1807. It is prepared by electrolysis from chloride of strontium. It is a golden-yellow metal, of considerable metallic lustre, harder than lead, and ductile. It melts at a red heat. Heated in air, it inflames and burns with a bright lustre in oxide. In dry air it remains unaltered; but it decomposes water, even at ordinary temperatures, with singular vehemence. Fuming nitric acid does not attack it: but dilute acids oxidize it readily. It burns in chlorine, iodine, bromine, and sulphur atmospheres, producing the corresponding compounds. Strontium has a specific gravity of 2.542, and an equivalent weight of 44. It is only in a strictly scientific light that this metal and its compounds are of any importance, excepting the chloride and nitrate, which are much used by pyrotechnists. The chemical symbol of the metal is *Sr*.

A few of its principal compounds are briefly described in the following:—

OXIDE OF STRONTIUM—*Strontia*.—This base is most easily obtained by igniting the nitrate. It is greyish-white, and of specific gravity 3.932. It is neither fusible nor volatile. For water it shows powerful affinity, and forms a *hydrate*. This is soluble in fifty times its weight of cold, and 2.4 parts of boiling water. From the latter it separates in crystals belonging to the square prismatic system. Nine equivalents

of water are easily expelled by heat; but it requires a temperature approaching white heat again to render the hydrate anhydrous. Both strontia and its hydrate readily absorb carbonic acid. The symbol of strontia is SrO , and the equivalent 52; the symbol of the hydrate is SrO , 9 H₂O.

CARBONATE OF STRONTIA is found native as strontianite, both massive, and in forms belonging to the square prismatic system. It is most readily prepared pure by precipitating the nitrate or chloride with carbonate of ammonia. The artificial carbonate is beautifully white and soluble in one thousand five hundred and thirty-six parts of boiling water. It is more soluble in aqueous solution of carbonic acid, and separates in needles when evaporated. Heated to bright redness in a stream of watery vapor it loses its carbonic acid, and becomes changed into strontia. The symbol is SrO , CO_2 ; Eq. 74.00; specific gravity, 3.605.

SULPHATE OF STRONTIA is the *celestine* of mineralogists. Sometimes massive, it is often found beautifully crystallized in prisms isomorphous with sulphate of baryta. Artificially it may be prepared by precipitation from any of its soluble salts, either by sulphuric acid or a soluble sulphate. It has the form of a white tasteless powder, soluble in fifteen thousand parts of cold, and three thousand eight hundred and forty parts of boiling water. In solutions of common salt it is slowly but completely soluble. A solution of sulphate of strontia precipitates salts of baryta. The symbol is SrO , SO_3 ; Eq. 92.00; specific gravity, 3.95.

NITRATE OF STRONTIA separates from concentrated solutions in transparent colorless octohedra, soluble in five parts of cold, and half their weight of boiling water; insoluble in alcohol. It has a sharp, cooling taste, and decrepitates in the fire, leaving strontia. At low temperatures it crystallizes out from more dilute solutions with five equivalents of water. Nitrate of strontia is much used by pyrotechnists to produce a splendid crimson flame. A mixture of forty parts of the nitrate, five of chlorate of potassa, thirteen of sulphur, and four of the sesquisulphide of antimony, is found a good one in practice, but *great care* is necessary in the admixture. The symbol is SrO , NO_3 ; Eq. 106.00; specific gravity, 2.704.

On the large scale the nitrate is prepared by heating pounded celestine with one-third of its weight of bituminous coal, dissolving the resulting sulphide in water, and decomposing with dilute nitric acid.

CHLORIDE OF STRONTIUM is in long, six-sided needles, deliquescent in moist air, and soluble in three-quarter parts of cold water. It imparts an intense crimson color to flame. In alcohol it is also soluble. When heated, the chloride melts and becomes speedily anhydrous. Ignited in air, it loses chlorine and absorbs oxygen. The chloride of strontium is most easily prepared by dissolving the sulphide in water, and decomposing with hydrochloric acid. The symbol for the salt is SrCl , 6 H₂O.

General Character of the Salts of Strontia.—They are colorless; not poisonous, like most of those of barium. Before the blowpipe they communicate a crimson color to flame. Neither hydrofluosilicic acid nor

hyposulphite of soda precipitates them. The chromate of strontia is sufficiently soluble to be employed as a test for baryta; but oxalic acid produces immediate turbidity in them. On addition of sulphate of lime to a solution of a salt of strontia, there arises gradually a white precipitate of sulphate of strontia; immediately when heated.

Strontia is always determined in analysis as sulphate or carbonate; one hundred parts of the former contain 56.52 of strontia, and of the latter 70.27 parts of this base.

SUGAR.—*Sucre*, French; *Zucker*, German; *Saccharum*, Latin.—Sugar seems to come more directly from the Persian *Shukkur*, which is nearly the same as the English pronunciation. The Arabic name is similar, and the probable origin of both is said to be the Sanscrit *Sarkara*. In the old Assyrian and Phœnician languages there was no letter *k*, but both nations called the substance *suicar* or *suiera*. It is said by HUMBOLDT to have been known in very early times in China. It is probable that in early historic times it was brought as a luxury and a curiosity into Western Asia and Europe. The Hebrew word for being intoxicated is *Shacar*, and strong drink *Shecar*. These words were believed to have an intimate connection with sugar; but this could only occur in a country where sugar was so well known that its ready passage into alcohol was familiar. Such was not the case in Western Asia or Syria and the surrounding countries in known times, although it may have been so at an earlier period. In the Bible is mentioned *sweet calamus* two hundred and fifty shekels; and *calamus* and *cinnamon* in SOLOMON'S Song; *sweet cane* in ISAIAH, and in JEREMIAH and EZEKIEL. There is little difficulty in believing the scriptural writers to be the earliest who allude to sugar. Persons in frequent communication with the East were sure to obtain its products before the Greeks. HERODOTUS speaks of manufactured honey, supposed to mean sugar; and STRABO mentions that NEARCHUS, one of ALEXANDER'S admirals, speaks of a reed which yields honey without bees in India. THEOPHRASTUS mentions it as a honey obtained from a reed which grew in moist places in Egypt, and had a sweet root. This sweet root has been used as a proof that he did not allude to the cane. The mention of moist places also is an objection; but so many canes do grow in moist places that one readily forgives this error and others, seeing that the fact of sweet matter from a cane is so distinctly spoken of. THEOPHRASTUS speaks of honey from reeds, evidently cane sugar. ERATOSTHENES alludes to roots in India sweet to the taste even when boiled, as if it were the custom to boil them to remove the sugar. VARRO speaks of the juice of an Indian root so sweet that, when pressed out, no honey can contend with it. DIOSCORIDES says that there is a kind of honey called *saccharus* which is found in reeds in India and Arabia Felix, having the appearance of salt; but it was only used in medicine. If found in Arabia it might well have been known early in Syria. PLINY says that there is a kind of honey which collects in reeds, white like gum, and brittle to the teeth; the larger pieces about the size of a filbert, and only used in medicine. STATIUS speaks

of boiling canes in Ebosita; but that place is not known. ARRIAN mentions it as an article of Indian commerce; and AELIAN speaks of it as pressed from reeds on the Ganges. It is well to add that Dr. ADAM, the learned editor of Paulus Egineta, says that the saccharum of THEOPHRASTUS, DIOSCORIDES, GALEN, STRABO, and PLINY was a concretion formed on various reeds, but especially on the bamboo cane; also, that MOSES CHORENENSIS, fifth century, first mentions the boiling of canes. This may account for the bitterness and medicinal qualities mentioned by DIOSCORIDES and others. ALBERTUS AGNENSIS relates that the crusaders found sweet honeyed canes in great quantity in the meadows near Tripoli in Syria, which reeds were called Zuera. These the crusaders sucked, and were much pleased with the sweet taste of them, with which they could scarcely be satisfied. This plant is cultivated, the author states, with great labor of the husbandmen every year. At the time of harvest they bruise it when ripe in mortars, and set by the strained juice in vessels, till it is concreted in the form of snow or of white salt. This, when scraped, they mix with bread, or rub it in water, and take it as pottage; and it is to them more wholesome and pleasing than the honey of bees. The people who were engaged in the sieges of Albaria Marra and Archas, and suffered dreadful hunger, were much refreshed thereby. Again, JACOBUS DE VITRIACO mentions reeds full of honey in Syria, pressed out by a screw and concreted by fire. WILLERMUS TYRENSIS speaks of it as being an article of export from Tyre; it seems to have at that time spread over all the Levant, and in the time of the Emperor BARBAROSSA it was made in Sicily, and used both solid and as a sirup. Sugar is said to have been imported into Venice as early as 991. It was brought from Sicily and Egypt—cheaper from Sicily—in the twelfth century. In 1166 WILLIAM II. gave a mill for grinding sugar canes to the monastery of St. Bennet. It travelled into Valencia, thence to Granada and Murcia. About 1420 the Portuguese took it to Madeira and Spain, and to the Canaries. Thence, says Dr. MOSELEY, the cultivation of the sugar cane and the art of making sugar were extended by different nations of Europe to the West Indian islands and the Brazils.

In 1518 there were twenty-eight sugar works established by the Spaniards in Saint Domingo; and HAWKINS brought some of the sugar to England in 1563. Antwerp had exported it about the same time—1560. The English planters were realizing great wealth in Barbadoes in 1650, although the Portuguese supplied the most of Europe then with Brazil sugars.

The name sugar is used in the arts to denote certain substances in the vegetal and animal kingdoms, whose chief characteristics are a sweet taste and the power of undergoing, either directly or indirectly, vinous fermentation, that is, of splitting up under the influence of yeast almost wholly into carbonic acid and alcohol. Four principal kinds of sugar are known, namely, *cane-sugar*, so called from the fact that its chief source is the sugar cane, though it is found in large quantities in other plants, such as the stalks of maize or indian corn, the maple, birch, palm, the beet-root, carrot, turnip, and in a large number of

tropical fruits; *fruit sugar* is that to which all these fruits owe their sweetness, and hence its designation; it does not crystallize, and exists in large quantities in treacle. The third variety is called *grape* or *starch sugar*, owing to its being found in ripe fruit, such as dried raisins, figs, and the like, or from the fact that it may be produced in quantities from starch; and the fourth kind, called *milk sugar*, is exclusively found in the lacteal fluid of animals.

A remarkable feature in all these varieties of sugar is, that two of the three elements of which they are composed, namely, hydrogen and oxygen, are so proportioned as to constitute water, or, in other words, they contain the same number of equivalents of these elements. This fact has led to sugars being designated *hydrates of carbon*; but from such terms it is not to be understood that the hydrogen and oxygen really exist as water, but rather that their combination, in the proportion in which they are found in the sugar admits of the expression. The composition of the different kinds of sugar varies only in the elements of one or more equivalents of water; to which fact may be attributed the readiness with which one species is changed into another, merely by the assimilation of that liquid. This feature in the composition of sugars extends to other substances not possessing the same properties, but readily convertible into particular kinds by certain chemical operations, such as the several starches, dextrin, inulin, gum, and several others. The following tabular view of the chemical composition of the sugars and a few of the above mentioned substances will at once exhibit the great analogy in composition between the two classes of bodies:—

Name.	Composition.
Cane sugar, or sucrose, . . .	$C_{24} H_{22} O_{22} = C_{12} H_{11} O_{11}$
Fruit sugar, or fructose, . . .	$C_{12} H_{12} O_{12} = C_{12} H_{12} O_{12}$
Starch sugar, or glucose, . . .	$C_{12} H_{12} O_{12}, 2 HO = C_{12} H_{14} O_{14}$
Milk sugar, or lactose, . . .	$C_{24} H_{19} O_{19}, 5 HO = C_{12} H_{12} O_{12} \times 2$
Manna sugar, or mellitose, . . .	$C_{24} H_{24} O_{24}, 4 HO = C_{12} H_{14} O_{14} \times 2$
Starch and gum group.	
Starch,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Dextrin,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Inulin,	$C_{24} H_{21} O_{21} = C_{12} H_{10} O_{10} \times 2 + HO$
Gum,	$C_{12} H_{11} O_{11} = C_{12} H_{11} O_{11}$
Cellulose,	$C_{12} H_{10} O_{10}$

From a comparison of the formulas in the foregoing table, it will be observed that the amount of carbon in the several varieties remains the same, but that the elements of water present slightly vary, and to these their distinct and diverse properties is to be attributed.

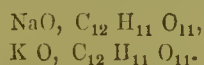
CANE-SUGAR. — *Common sugar* is manufactured chiefly from the sugar cane, but large quantities are prepared also from the sap of the maple tree and from beet-root.

Preparation.—To make pure cane-sugar the same course of operations should be followed as will be described in preparing and refining sugar, each being executed with greater care and attention; hence it will be needless to detail the process here.

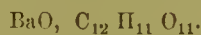
Properties.—Cane-sugar when pure, as in the finest lump, has a glistening white appearance, resulting from the multifarious reflections and refractions of light from the numerous congeries of small crystals composing it. When a very concentrated solution of this substance is left to crystallize spontaneously, it forms rhomboidal prisms with dihedral summits of considerable dimensions, especially if the nuclei be transferred repeatedly to concentrated menstrua. Thus crystallized it forms the sugar candy of the shops, and appears transparent. According to PLAYFAIR and JOULE its specific gravity is 1.594. It is soluble in about one-third of its weight of cold, and in all proportions in boiling water, forming in either case transparent colorless sirups. A solution saturated with sugar at 212° deposits a part in crystals—the candy already mentioned—on cooling. If the temperature at which the saturation is effected be raised to 230°, the whole forms a concrete granular mass when allowed to cool. This is not the case when the sirup is rapidly boiled down to the same density; for then it congeals on a cold surface in a transparent amorphous mass, which on exposure becomes opaque, owing to a fibrous crystallization radiating from the surface inwardly. In this state it is ordinarily called *barley sugar*, the change from the crystalline state being due to a dimorphism caused by the heat, analogous to that which sulphur exhibits under almost similar circumstances. Continuous boiling of a weaker sirup has a like effect. The same change, from the crystallizable to the noncrystallizable modification is effected in the cold by the prolonged contact of dilute mineral acids. Noncrystallizable cane-sugar has the composition $C_{12} H_{11} O_{11}, HO$. It is gradually converted by long-continued contact with water, especially in the presence of acids, without undergoing any chemical change, into glucose or grape-sugar— $C_{12} H_{12} O_{12}, 2 HO$ —a substance which crystallizes in acicular tufts. Dilute alcohol of specific gravity 0.830 takes up about a quarter of its weight of sugar. Absolute alcohol dissolves a small quantity of it at the boiling point, but deposits it again on cooling. When the crystals of candied sugar are broken, a slight phosphorescence is discernible, and a similar phenomenon is produced on rubbing two pieces of lump sugar together. Heated to 212°, no further effect is produced on crystallized cane-sugar than the expulsion of the mechanical moisture contained in its interstices. At 320° it melts; and though not decomposed, still, as PROUT remarks, several of its characteristics are destroyed. Between 320° and 350° the liquid mass becomes transparent on cooling, though, from circumstances such as those mentioned in reference to barley sugar, the transparency is destroyed after some time. At 410° it changes to an orange-yellow, afterwards to a reddish-brown hue; and if this heat be maintained, it is converted into a new acid compound of a brownish color very soluble in water—*caramel*—with the loss of three equivalents of water. If the heat be further increased, complete decomposition takes place, with evolution of inflammable gases mixed with carbonic acid, pyrogenous oils, and acetic acid; and a carbonaceous residue, forming about

a quarter of the weight of the original substance, remains.

Cane-sugar combines directly with the oxides of the alkalies and of the alkaline earths, forming with them sugarates—improperly called sometimes saccharates; and also with certain salts, particularly with chloride of sodium. The potassa and soda compounds, which are both unstable and indefinite, are obtained as sirupy liquids on adding a strong aqueous solution of the alkali to a solution of sugar in alcohol. Their compositions are—

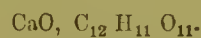


Sugarate of baryta is formed by dissolving one part of caustic baryta in three parts of hot water, and adding the solution to a sirup containing two parts of sugar and four parts of water. A mass of crystals is thus obtained resembling boracic acid, and having the composition—



Sugarate of baryta is difficultly soluble in water, and is decomposed by almost all acids into the corresponding baryta, salt and sugar. Even the carbonic acid of the air effects this change.

There appear to be three sugarates of lime, of which however the most definite and important has the composition—

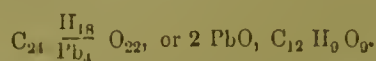


This is formed on adding milk of lime to sirup, in the proportion of two parts by weight of lime to thirteen of sugar. After filtration the sugarate of lime is precipitated by alcohol. On drying, this body appears frangible and resinous, and is very soluble in water. This compound has the rare property of being precipitated from its aqueous solution by heat, and of redissolving as it cools. The amount of lime which a sirup takes up is less according as the density of the sirup is greater. The following table constructed by PELIGOT shows this relation—

Quantity of sugar dissolved in 100 parts of water.	Density of sirup.	Density of sirup when saturated with lime.	100 parts of residue dried at 120° contain			
			Lime.	Sugar.		
40.0	..	1.122	..	21.0	..	79.0
37.5	..	1.116	..	20.8	..	79.2
35.0	..	1.110	..	20.5	..	79.5
32.5	..	1.103	..	20.3	..	79.7
30.0	..	1.096	..	20.1	..	79.9
27.5	..	1.089	..	19.9	..	80.1
25.0	..	1.082	..	19.8	..	80.2
22.5	..	1.075	..	19.3	..	80.7
20.0	..	1.068	..	18.8	..	81.2
17.5	..	1.060	..	18.7	..	81.3
15.0	..	1.052	..	18.5	..	81.5
12.5	..	1.044	..	18.3	..	81.7
10.0	..	1.036	..	18.1	..	81.9
7.5	..	1.027	..	16.9	..	83.1
5.0	..	1.018	..	15.3	..	84.7
2.5	..	1.009	..	13.8	..	86.2

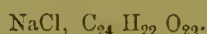
The hydrated oxide of copper is dissolved by a mixture of sugar and sugarate of lime, an amorphous double sugarate of lime and copper being formed. The sugarate of lead is not strictly an analogue of the previously described metallic compounds of sugar, which are formed by the direct union of the sugar with the metallic oxide. Sugarate of lead is sugar in

which four atoms of hydrogen are replaced by four atoms of lead—



It is produced as a gelatinous precipitate on mixing an ammoniacal solution of acetate of lead with a solution of sugar. After washing with cold it is dissolved in hot water, and allowed to stand closed from the air. The compound gradually separates out as white crystals. Massicot also gradually combines with sugar, forming the same compound, water being liberated at the same time.

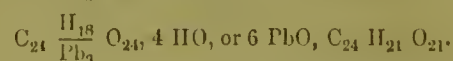
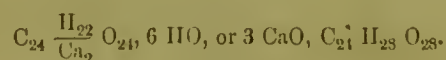
The chloride of sodium likewise combines directly with cane-sugar. If four parts by weight of sugar and one part of chloride of sodium be dissolved together in water, and allowed to evaporate spontaneously, the excess of sugar first crystallizes out; the mother-liquor, on further evaporation, deposits crystals which deliquesce in moist air, of the composition, according to GERHARDT, of—



GLUCOSE, or grape-sugar, occurs in raisins, currants, and other dried ripe fruits, and in flowers. It occurs also in honey and in the urine of patients affected with diabetes, accompanying in all the above cases non-crystallizable cane-sugar. It is found also in the blood, the bile, and in eggs. Both starch and cellulose are converted into glucose by digestion with dilute sulphuric acid. The substance which appears near the germinating point at the time of germination of the cereals, called diastase, or in its crude and impure form, yeast or barm, has also the power of transforming starch into grape-sugar, for there is no evidence to show that the substance which changes starch to glucose, is other than that which changes glucose into alcohol and carbonic acid.

Aqueous alcohol dissolves all these kinds of sugar, cane-sugar, grape-sugar, and noncrystallizable sugar, in proportions greater according to the degree of dilution of the alcohol. Absolute alcohol dissolves the non-crystallizable sugar alone. This behavior is made the basis of a method of assaying sugars, as will be shown further on.

For further particulars concerning the properties and composition of this substance, see article STARCH—sub-heading *Glucose*—page 962. Glucose, like *sucrose* or cane sugar, combines with the metallic oxides to form the following glucosates—



It also combines with chloride of sodium forming—



Glucose forms with sulphuric acid a copulated acid whose salts are both unstable and incompletely examined. With nitric acid a detonating compound is produced. Mannite forms with nitric acid a similar detonating body.

MANNITE— $C_{12} H_{14} O_{12}$ —called also the sugar of mushrooms, is chiefly extracted from manna, an exudation from the *Fraxinus rotundifolia*; it is also found in celery, dog's tooth, fennel, *et cetera*, and in agave. Mannite is one of the products of the fermentation of starch and glucose; it is produced in the transformation of starch into glucose by dilute sulphuric acid. It is readily obtained from manna by boiling it with strong alcohol; on filtering and allowing the filtrate to cool, it crystallizes out, and is purified by recrystallization from alcohol. Mannite does not readily ferment. Owing to this, it may be freed from the other sugars by submitting the liquid which contains them all to fermentation, and extracting the mannite from the unfermented residue. It is supposed that the gradual loss of sweetness effected by time in wine is chiefly due to the slow transformation which the mannite they retained after the first fermentation undergoes. Direct experiments have shown that mannite does suffer such a fermentation.

Sugar of Milk— $C_{12} H_{20} O_{20}, 2 HO$ —otherwise called lactine or lactose, occurs in the milk of the mammiferae, from which it is extracted by precipitating the caseum by a dilute acid, filtering, and evaporating to dryness.

Sorbine— $C_{24} H_{24} O_{24}$ —is found in a few plants.

Mosite— $C_{24} H_{24} O_{24}, 4 HO$ —occurs in the juice of flesh, it is very soluble in water; insoluble in alcohol and ether; at 212° it loses four atoms of water.

Cane-sugar, both crystallizable and noncrystallizable, and glucose, are all capable of alcoholic fermentation. But the action of the ferment is, in the first place, to transform both the former kinds of sugar into glucose or grape-sugar.—See ALCOHOL.

Testing or Estimation of Sugar.—If a watery solution contains only one of the three kinds of sugar—namely, cane-sugar, crystallizable; cane-sugar, non-crystallizable; or grape sugar, glucose; the amount of sugar may be determined from the specific gravity of the sirup. In all cases the density of the sirup is increased by an increased quantity of saccharine matter.

The following table from Dr. URE's Dictionary shows the specific gravity at 60° of solutions of crystallizable cane-sugar containing various amounts of sugar in one hundred parts by weight of the sirup:—

Sugar in one hundred parts by weight.	Specific gravity at 60°
66.666	1.3260
50.000	1.2310
40.000	1.1777
33.333	1.1400
31.250	1.1340
29.412	1.1250
26.316	1.1110
25.000	1.1045
21.740	1.0905
20.000	1.0820
16.666	1.0685
12.500	1.0500
10.000	1.0395

The subjoined more extended table has been constructed by PAYEN for a similar purpose. It shows the density at 59° of sirups formed by dissolving one hundred parts by weight of sugar in different quantities of water. The values differ somewhat widely from those given by Dr. URE:—

Parts of sugar.	Parts of water.	Specific gravity.
100 dissolved in	50 give a sirup of	1.345
100	60	1.322
100	70	1.297
100	80	1.281
100	90	1.266
100	100	1.257
100	120	1.222
100	140	1.200
100	160	1.187
100	180	1.176
100	200	1.170
100	250	1.147
100	350	1.111
100	450	1.089
100	550	1.074
100	650	1.063
100	750	1.055
100	945	1.045
100	1145	1.030
100	1945	1.022
100	2415	1.018
100	2945	1.015

The annexed table, constructed by NEIMANN at the normal temperature of 63°, with the same object, is also submitted:—

Sugar.	Water.	Specific gravity.	Sugar.	Water.	Specific gravity.
0 ..	100 ..	1.0000	36 ..	64 ..	1.1582
1 ..	99 ..	1.0035	37 ..	63 ..	1.1631
2 ..	98 ..	1.0070	38 ..	62 ..	1.1681
3 ..	97 ..	1.0106	39 ..	61 ..	1.1731
4 ..	96 ..	1.0143	40 ..	60 ..	1.1781
5 ..	95 ..	1.0179	41 ..	59 ..	1.1832
6 ..	94 ..	1.0215	42 ..	58 ..	1.1883
7 ..	93 ..	1.0254	43 ..	57 ..	1.1935
8 ..	92 ..	1.0291	44 ..	56 ..	1.1989
9 ..	91 ..	1.0328	45 ..	55 ..	1.2043
10 ..	90 ..	1.0367	46 ..	54 ..	1.2098
11 ..	89 ..	1.0410	47 ..	53 ..	1.2153
12 ..	88 ..	1.0456	48 ..	52 ..	1.2209
13 ..	87 ..	1.0504	49 ..	51 ..	1.2265
14 ..	86 ..	1.0552	50 ..	50 ..	1.2322
15 ..	85 ..	1.0600	51 ..	49 ..	1.2378
16 ..	84 ..	1.0647	52 ..	48 ..	1.2434
17 ..	83 ..	1.0698	53 ..	47 ..	1.2490
18 ..	82 ..	1.0734	54 ..	46 ..	1.2546
19 ..	81 ..	1.0781	55 ..	45 ..	1.2602
20 ..	80 ..	1.0830	56 ..	44 ..	1.2658
21 ..	79 ..	1.0875	57 ..	43 ..	1.2714
22 ..	78 ..	1.0920	58 ..	42 ..	1.2770
23 ..	77 ..	1.0965	59 ..	41 ..	1.2826
24 ..	76 ..	1.1010	60 ..	40 ..	1.2882
25 ..	75 ..	1.1056	61 ..	39 ..	1.2933
26 ..	74 ..	1.1103	62 ..	38 ..	1.2994
27 ..	73 ..	1.1150	63 ..	37 ..	1.3050
28 ..	72 ..	1.1197	64 ..	36 ..	1.3105
29 ..	71 ..	1.1245	65 ..	35 ..	1.3160
30 ..	70 ..	1.1293	66 ..	34 ..	1.3215
31 ..	69 ..	1.1340	67 ..	33 ..	1.3270
32 ..	68 ..	1.1388	68 ..	32 ..	1.3324
33 ..	67 ..	1.1436	69 ..	31 ..	1.3377
34 ..	66 ..	1.1484	70 ..	30 ..	1.3430
35 ..	65 ..	1.1538			

The following is most used:—

TABLE OF THE DENSITY OF SOLUTIONS OF SUGAR, ACCORDING TO BEAUMÉ.

Degrees.	Sugar per cent.	Degrees.	Sugar per cent.	Degrees.	Sugar per cent.
1	1.8	13	23.7	25	46.2
2	3.5	14	25.6	26	48.1
3	5.2	15	27.6	27	50.0
4	7.0	16	29.4	28	52.1
5	8.7	17	31.5	29	54.1
6	10.4	18	33.4	30	56.0
7	12.4	19	35.2	31	58.0
8	14.4	20	37.0	32	60.1
9	16.3	21	38.8	33	62.2
10	18.2	22	40.6	34	64.4
11	20.0	23	42.4	35	66.6
12	21.8	24	44.3		

PAYEN gives the subjoined empirical formula for the estimation of the amount of sugar in a sirup from the indications of its gravity with BEAUMÉ's areometer, namely—multiply the indicated density by two and deduct a tenth of the product, the remainder will represent the per centage of sugar in the liquor. Thus, if the indication observed be 20, the result will be—

$$20 \times 2 \text{ minus } \frac{20 \times 2}{10} = 36.0 \text{ per cent.}$$

If the sirup be of pure crystallized sugar the product of the density multiplied by two is reduced by one-twelfth; thus—

$$20 \times 2 \text{ minus } \frac{20 \times 2}{12} = 36.67 \text{ per cent.}$$

If, however, a sirup contains other solid bodies besides sugar, it is clear that the specific gravity of the solution alone can give only an imperfect criterion of the quantity of sugar present. Recourse is then had to the power which a solution of cane-sugar has of turning to the right the plane of polarized light. When therefore a liquid contains cane-sugar without any other substance possessing the same optical property, the quantity of sugar may be determined with great exactness by measuring the deviation which the liquid produces in the plane of polarization. To apply this method, the deviation must be known which is produced by a solution of sugar of known strength. For this purpose a given weight, ϵ , of sugar is dissolved in such a quantity of distilled water that the solution occupies a given volume, V . Sufficient of this solution is taken to fill a tube of a certain length, and the deviation suffered by the plane of polarization of the luminous ray passing through this tube is measured. Let this deviation be α . Let then other quantities of sugar be dissolved in sufficient water to give the same volume of solution, V ; and let the deviations produced by these solutions in the same tube be α' , α'' , α''' , *et cetera*; then the quantities of sugar contained in the volume, V , of these liquids will be represented by

the products $\epsilon \frac{\alpha'}{\alpha}$, $\epsilon \frac{\alpha''}{\alpha}$, $\epsilon \frac{\alpha'''}{\alpha}$, *et cetera*, respec-

tively. If the sugar examined, instead of being pure, is mixed with other but inactive substances, it is evident that these same products express the absolute weights of pure sugar contained in the weights of substances employed in the formation of the liquids of the given volume, V . It is possible to employ proof tubes of different lengths; but it is then necessary to reduce by calculation the observed deflections to those which would have been produced in the same tube.

It often happens that solutions of sugar which have to be examined are turbid or strongly colored. When this interferes with the examination, they must be clarified and rendered either quite colorless, or when this is not possible the color must be at least reduced. This may generally be effected by precipitating the coloring matter of the sirups with subacetate of lead; but at a sugar-work the most convenient and complete method is a filter of animal charcoal. The filtrates are then examined optically. When sirups

contain, besides cane-sugar, other constituents which exert an action upon the plane of polarization, the amount of cane-sugar present may be often determined by inverting, by means of hydrochloric acid, the rotary power of the cane-sugar. No other saccharine substance is, in fact, known which suffers a similar change under the same circumstances.

If, for instance, the liquid under examination contains besides cane sugar, glucose, whose rotary action on the plane of polarization is in the same direction as that of cane sugar; if α' be the deviation observed to be produced by the liquid, then α' is evidently the sum of the separate deflections of the cane-sugar, x , and of the glucose, y . About one-tenth of its volume of hydrochloric acid is added to the sirup, and it is kept for ten minutes at a temperature of 140° – 154° . The cane-sugar is thereby completely transformed into noncrystallizable sugar, which turns the plane of polarization to the left, while the rotary power of the glucose undergoes no alteration. When this change has been effected, the new deviation, α'' , of the liquid is observed. It is now the difference between the deviation, y , of the glucose and that of the noncrystallizable sugar derived from the cane sugars. But the degree of dilution of the liquid having been changed by the addition of the hydrochloric acid, the deviation observed, α'' , must be replaced by the deviation, $\frac{10}{9} \alpha''$, which would have

been observed if the inversion could have been produced without the addition of hydrochloric acid. Admitting therefore that a quantity of cane-sugar which effects a deviation, x , gives rise to a quantity of noncrystallizable sugar which effects a deviation, rx , there is—

$$\text{Before the inversion, } x + y = \alpha'.$$

$$\text{After the inversion, } y + rx = \frac{10}{9} \alpha''.$$

From these two equations the quantities x and y may be determined. The coefficient of inversion, r , is determined once for all by a special experiment performed upon pure cane-sugar at the temperature at which the experiments have afterwards to be made. According to Biot, this coefficient is 0.038 for hydrochloric acid at a temperature of 71.6° .

The process is the same when the cane sugar is mixed with noncrystallizable sugar, turning the plane of polarization to the left. In this case the initial deviation, α' , of the liquid is the difference between the deviation to the right, x , of the cane-sugar, and the deviation, z , to the left of the noncrystallizable sugar. After treating with hydrochloric acid, the deviation, α'' , is composed of the deviations of the original noncrystallizable sugar, and of that produced by the action of the hydrochloric acid. One then has—

$$\text{Before inversion, } x - z = \alpha'.$$

$$\text{After inversion, } z + rx = \frac{10}{9} \alpha''.$$

It is important in examining optically noncrystallizable sugar always to employ the same temperature,

because a change of temperature materially affects the rotary power of this kind of sugar.

E. MAUMÉNT proposes chloride of tin— SnCl_2 5.110—as a reagent for sugar. By boiling he obtains a constant result. One part of sugar evaporated with thirty to thirty parts of chloride of tin, and heat 100° to 220° or 225° , produces a brown body, insoluble in acids and alkalis. This he calls caramelin. It consists of $\text{C}_{12} \text{H}_{14} \text{O}_4$. Grape-sugar, cellulose, dextrin, and other bodies, give the same compound.

According to HORSLEY, alkaline chromate of potash produces a green color in solutions of sugar, easily detected in a few drops.

FEHLING analyses sugar metrically in a beautiful way; but it is better suited to minute quantities than to the work of a sugar-house. He has a normal solution, made of—

40 grammes of sulphate of copper,
160 grammes of neutral tartrate of potash, or 200 grammes of tartrate of soda.

700—800 grammes of caustic soda, specific gravity 1.12.
This is diluted with water to 1154.5 cub. c.

Of this solution 1 cub. c. = 0.0050 grape-sugar, or 0.00475 cane-sugar.

Grains may be used instead of grammes, and then 1 grain = 0.0050 grape-sugar, without change of calculation.

100 parts of grape-sugar,
95 “ cane-sugar,
90 “ starch, } = 220.5 CuO, or 195 CaO .

This mode is peculiarly valuable for urines, as it measures the smallest quantities. The urine should be diluted from ten to twenty times with water. It should be boiled a few seconds after adding each portion of copper solution. The sugar of urine is grape-sugar.

On the Manufacture of Cane-sugar.—The manufacture of sugar from the sugar-cane may be divided into five parts. 1. *The cultivation of the cane.* 2. *The extraction of the juice.* 3. *The purification of the juice.* 4. *Its concentration;* and 5. *its crystallization.*

1. *Cultivation of the Cane.*—The sugar-cane—*Arundo saccharifera*—is an indigenous plant of the gramineæ family. Cultivators distinguish three great varieties—the Creole, the Batavian, and the Otaheite cane. The first is indigenous to India; but it has been transplanted to other soils, such as those of Sicily, the Canaries, the Antilles, South America, and the West Indies. It is known by its thin, very knotty stem, and green leaves. The Batavian cane is a native of Java, but is met with at present in some of the sugar plantations of the New World and the West Indies; it is covered with purple stripes, and has a heavy foliage. The Otaheite variety is spread over the West Indies and South America, and is esteemed by far the richer and more productive of the several species. There are besides, the purple-banded and the purple Otaheitian and the ribbon cane. The Bourbon is said to be the same as the Otaheite cane of Singapore.

The sugar cane in a state of maturity is usually from six to fifteen feet in length, and from one and a half to two inches in diameter. It is jointed, and the distance of the joints from one another is from three to seven inches. These joints correspond to the extremities of hexagonal cells of which the intermediate

portions of the stem are composed, and which are in the living state of the plant filled with a solution of sugar. The exterior of the cane is smooth, hard, and cylindrical, and is covered with a coating containing a large quantity of silica. Germination occurs at the joints, and takes place at the opposite sides of alternate joints.

The sugar cane grows from pieces or slips of itself containing germs, and these develop rootlets at the joints, which draw sustenance to the young shoot as it increases. In the course of time the buds in the radicle, or root joints, of the first cane throw out roots, and form a radicle for a second stem; and in this way it happens, under favorable circumstances, that several canes are produced from the parent stock for a period of about six years, sometimes even for twenty years. From the first and second year, however, the canes diminish in the length of joint and circumference, and so the quantity of juice decreases; but it is alleged that the juice is much richer than when younger, and also produces a finer sugar. A common mode of obtaining successive crops is as follows:—When an old cane has been cut for its sugar, the incision is made some inches below the ground and the stump covered with mould. In about twelve months' time the offshoots from the original cane are ready for transplanting. In planting these slips or *ratoons* the system of wide planting is gradually superseding the old close planting. In addition to the advantage which the former kind offers in allowing the use of the horse-hoe for weeding, the great length of the root of the sugar-cane, which often extends laterally to a distance of six, and vertically to a depth of two feet, makes wide planting imperative, when rapidity of growth, as determined by quick absorption, is required. The cane holes are advantageously formed five feet from one another, in rows which are also five feet apart.

Of late years the system of cultivation of the sugar-cane has attracted considerable attention, as well in regard to the preparation of the soil as to the manner of planting. Formerly the custom of preparing the land by manual labor was followed; it is sometimes so still, and the consequence of not having the soil sufficiently disintegrated to the proper depth required by the plant, made itself apparent in the defective harvests of the plantations which followed; besides, by the practice of utilizing for fuel the *magass* or expressed cane, called *cane straw* and *cane trash*, instead of returning it to the land, the latter was rendered deficient in humus, and, therefore, not suited to retain the proper quantity of moisture, which, in the warm climates of its growth the cane absolutely requires for its proper development. And, although the ashes of the refuse might be consigned to the soil, yet this, instead of improving, rather defeated the objects which the cultivators had in view, as by the use of too much mineral matters as a manure, the sugar secreted by the plant was rendered uncrystallizable, and so, in a comparative sense, lost to the planter. An excess of soluble salts should always be guarded against in the cultivation of the sugar plant; but the fertilizer should be rich in humus and nitrogenous constituents, as the consumption of both these classes of bodies by the plant is greater in a much larger proportion than of mineral

fertilizing matters. The knowledge of these facts has led to the desire of employing such matters as blood, decomposed flesh, rotten fish, wool refuse, and the like, for manure in the sugar plantations. Charred peat would, in the opinion of the Editor, be a valuable adjunct to such matters, as it would materially prevent evaporation of the natural moisture of the soil, and supply carbon to the growing plant. Another feature in the modern innovations on the old system of culture is, that the *ratoons* or *stocks* are planted much wider apart. Various parties differ in their views in this respect—some recommending the plants to be set four feet apart in rows six feet asunder; others recommend a greater distance between the rows, such as eight feet; while some state that this should be increased to ten, or that each *stock* ought to have a space allotted to it of six and eight feet either way from the next one. It is to be hoped that from considerations like these, of the necessity of pursuing a more rational course of tillage, the planter may, and he doubtless will, be led, in the course of a few years' practice, to adopt the mode which enlightened observation and study will show to be most advantageous.

The frequent droughts which occur in the countries adapted to the cultivation of the sugar plant, render the artificial prevention of the too rapid evaporation of the water, which would be very injurious to the freshly-planted ratoons, of the highest importance. The great bulk and solidity, and the richness in mineral constituents of the stem of the sugar-cane, would cause a rapid impoverishment of the soil, were not some adequate return made to it. Both purposes are effected by surrounding the stems of the newly-planted ratoons with the *megass* or cane from which the sugar has been extracted.

Canes require a well drained but still a rich and moist soil. Land with much saline matter is frequently found to prevent the canes ripening; they remain green and watery.

One variety greatly in cultivation in Jamaica came from Otaheite. When this cane is well cultivated, and in favorable soil, it rises in the first year to twelve or fourteen feet in height, being six inches in circumference, and having joints six inches apart. No field, however, will give an average so high as this. Plants such as these will produce two and a half to three tons of dry sugar per acre, but the average is considered good at two tons per acre. It sometimes attains maturity in ten months. Its foliage is of a pale green; leaves broad and much drooping, and flowering or arrowing in a manner graceful and ornamental. It requires a rich soil. The *yellow violet* may be put in poorer soil. It gives a fine sugar, but not so much as the Tahiti cane. It has a dark-green foliage. The juices of the two are frequently mixed. The *purple violet* is from Java, and is eight to ten feet high, and six inches in circumference. On the joints of the cane there is a large amount of a resinous film, which sometimes completely shades the purple beneath. This resin is very hard and troublesome to grind. The sugar of this cane is excellent. The cane itself is hardy, and is sometimes used in Jamaica as a border to other canes, defending them against the trespassing of cattle.

The large red cane of Assam is said to flower in eight months, and to give similar sugar to the Tahiti cane. In Bengal a large red cane is cultivated which gives excellent sugar. The China cane is said to be extremely hardy, standing both cold and drought, and, with abundant rain, giving out as many as thirty shoots. It resists the inroads of the white ants, which cannot penetrate its hard crust, whilst it is also safe against the teeth of the jackals. It requires, however, a stronger mill for grinding than the other varieties mentioned. Mr. WRAY asserts that the Salangore cane is the finest in the Straits of Singapore, and perhaps in the world. He says that he has cut five from one stool, which were of a weight of from seventeen to twenty-five pounds. They have been known to produce seven thousand two hundred pounds of undrained sugar per acre, equal to five thousand eight hundred of dry sugar for shipping.

Dr. LIVINGSTONE says that sugar is cultivated in the Shire valley, as well as many parts of Africa near the Zambesi, and may be had for as little as one half-penny per pound. There is field enough for great enterprise in that direction. The amount obtainable has not been investigated.

The time of harvesting the cane varies with the mildness of the season, the locality, the nature of the soil, and the variety of the cane cultivated. Generally a dry, smooth, brittle skin, a heavy cane, a grey pith,

approaching to brown, and a sweet glutinous juice, indicate the maturity of the cane. A dry season is the time in which the canes should be cut, if possible, so that, by the absorption of too much moisture, the juice may not be diluted, and thus occasion no trouble and expense in preparing the sugar from it. The canes are cut as close to the *stole* or root as possible, as well because the lower joints are found richer in sugar, as to give vigor to the ratoons, which are to spring from the old stock; the tops, with one or two joints, if they be not sufficiently ripe, are cut off, and the canes tied in bundles, and conveyed to the crushing mill. It is absolutely necessary that the cane be cut just before expressed in the mills; for, if allowed to remain any length of time at the high temperature of the climate, the sugar ferments, and a considerable loss is consequently occasioned.

Dr. EVANS gives the products of an acre of canes in Barbadoes as—

Weight of canes.	Weight of juice.	Extract.	Extract per 100 pounds of juice.	Extract per 100 pounds of cane.
30 tons. . .	60,480 lbs. . .	10,886 lbs. . .	18.0 . .	16.25
30 tons. . .	47,040 lbs. . .	8467 lbs. . .	18.0 . .	12.6
30 tons. . .	33,600 lbs. . .	3500 lbs. . .	10.0 . .	5.0
30 tons. . .	33,600 lbs. . .	7280 lbs. . .	21.6 . .	10.2

An acre may be said to yield thirty tons of cane. The following table gives the produce in juice and sugar:—

Juice obtained per cent.	Juice in pounds.	Pounds of Sugar.			Subtract for Molasses and Skimmings, at 12 per cent.			Pounds of dry Sugar yielded by one Acre.		
		At 18 per cent.	At 20 per cent.	At 22 per cent.	At 13 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.
70 . . .	47,040 . . .	8,468 . . .	9,408 . . .	10,348 . . .	705 . . .	792 . . .	862 . . .	7,763 . . .	8,616 . . .	9,486 . . .
75 . . .	50,400 . . .	9,092 . . .	10,080 . . .	11,088 . . .	757 . . .	840 . . .	924 . . .	8,335 . . .	9,240 . . .	10,164 . . .
80 . . .	53,760 . . .	9,676 . . .	10,752 . . .	11,827 . . .	806 . . .	896 . . .	994 . . .	8,871 . . .	9,856 . . .	11,173 . . .

This supposes the juice to stand at 10° Beaumé; at the same time all the numbers given are above the amount actually obtained in practice, which does not appear to be above five thousand pounds per acre.

But it is difficult to tell the real amount of sugar obtained on the estates. The books on the subject are frequently very one-sided, or very confused, or they are not possessed of the information except for certain estates. Perhaps four thousand pounds of sugar and one hundred and seventy gallons of rum, twenty per cent. over proof, is a very fair specimen of the yield.

The following table by M. DUPREZ is given by Dr. EVANS. The average amount of juice from one hundred pounds of canes was—

1. By mills having horizontal rollers—motive power not stated—probably steam 61.2
2. By mills, motive power steam 60.9
3. By mills, motive power wind and steam 59.3
4. By mills having vertical rollers 59.2
5. By mills, motive power cattle 58.5
6. By mills, motive power wind 56.4

but 70 can now be obtained by greater power, and some speak of 80.

Of the eighteen to twenty-two per cent. of sugar in the cane, it is generally believed that no more than eight is obtained crystallized.

If only fifty per cent. of the juice is taken from the plant, and thirty still remain in it, three-eighths of the sugar are taken away in the megass and burnt

as fuel. Sugar must be to the planter at least worth twenty pounds per ton, whereas he could get coal from England at one pound. But this would not be an important loss, it is said, if the ashes of the megass were only taken and thrown on the soil, as was shown by Dr. STENHOUSE. The climates which grow sugar grow ligneous fibre rapidly, and it is well to use it for fuel when it can be obtained. The ground, however, must not be deprived of its inorganic constituents. It is also important to use the megass early, as the sugary matters unavoidably left in it oxidize, and, of course, give less heat in burning. It is well, however, to burn as little sugar as possible, at the same time to avoid an excess of soluble salts.

The following tables are from PAYEN:—

OTAHITE CANE AT MATURITY.

	Centesimally
Water,	71.04
Sugar,	18.00
Cellulose, ligneous matter, pectin, and pectic acid, . . .	9.56
Albumen and three other nitrogenous matters,	0.55
Cerosin, green matter, yellow coloring substance, substance capable of being dyed brown, and carmine, fatty matter, resins, essential oil, aromatic matter, and a deliquescent substance,	0.37
Insoluble salts 0.12; soluble 0.16; consisting of phosphates of lime and magnesia, alumina, sulphate and oxalate of lime, acetates, malate of lime, potassa, and soda, alkaline chlorides, and sulphates,	0.28
Silica,	0.20
	100.00

CANE ONLY AT A THIRD OF ITS DEVELOPMENT.

	Centesimally.
Water,	79.70
Sugar,	9.06
Cellulose and incrustated ligneous matter,	7.03
Albumen and three other nitrogenous substances,	1.17
Starch, cerosin, green matter, yellow coloring substance, and bodies colorable to brown and carmine, }	1.09
Fatty, aromatic, and hygroscopic substances, essential oil, soluble and insoluble salts, alumina, and silica,	1.95
	100.00

The fresh cane has been estimated to contain—

	Tahiti. Per cent.	Cuba. Per cent.
Water	72.1	65.9
Ligneous fibre.....	9.9	16.4
Sugar and other substances	18.0	17.7
	100.0	100.0

The juice of Martinique cane has been found to contain—

Sugar	20.9
Water	77.2
Organic substances not sugar	0.2
Inorganic salts	1.7
	100.0

The megass or residue, after passing the rollers—

Sugar	7.9	7.3
Molasses	3.0	2.7
Ligneous matter and earthy salts	38.6	39.5
Water	50.5	50.5
	100.0	100.0

CASASECA has analyzed the Havana cane—the *creole*—and found—

	Cane entire.	Cane peeled.	The rind.
Water	77.0	77.8	69.5
Sugar and soluble substances	12.0	16.2	11.5
Ligneous matter.....	11.0	6.0	19.0

He says that 23 of dry cane contain 12 of sugar, and 23 of the dry rind only 8.6.

	Cane sugar.	Grape sugar.	Water	Ashes	Water of the insoluble part.	Remainder—caramel, gum, and acids.
Ten sorts of Java	98.6 — 83.1	5.5 — 0.3	6.1 — 0.3	1.9 — 0.2	0.2 — 0.0	3.5 — 0.5
Six sorts of Havana	97.0 — 87.3	3.7 — 0.9	3.5 — 0.9	1.1 — 0.0	0.3 — 0.0	4.5 — 0.4
Four sorts of Surinam ..	92.3 — 85.4	4.4 — 1.6	6.3 — 3.6	1.4 — 0.8	0.6 — 0.4	2.1 — 1.1
Pure candy	99.6	0.1	0.2	0.1	—	—
White sugar	99.7	0.2	0.1	—	—	—

Twelve kilogrammes of molasses of cane sugar contain according to PAYEN—

Sugar	7.561.00
Acetate of potassa	0.209.30
Chloride of potassium	0.114.60
Sulphate of potassa	0.085.50
Mucilaginous matter	0.076.30
Phosphate of lime	0.052.00
Nitrogenous substances.....	0.050.00
Silica	0.023.90
Acetate of lime	0.016.20
Phosphate of copper	0.000.20
Water	1.800.00
Glucose and uncrystallizable sugar	1.561.00

RICHARDSON found sugar and the molasses from it to contain—

	Sugar.	Molasses.
Potassa	19.42	36.23
Lime	14.67	12.72
Magnesia	10.72	11.14
Oxide of iron	6.55	2.62
Oxide of copper	0.71	trace of
Protoxide of manganese...	trace	both

The amount of water in the sugar-cane increases according to CASASECA, towards the top; the greatest amount of sugar is found in the lower third of the cane, but much less in the upper part; the centre third contains about an average of the whole. The water even of the joints increases on rising.

The pure or nearly pure juice, when the green matter is removed, contains—

	Per cent.
Water	81.00
Sugar	18.20
Organic matter, precipitated by lead salts ...	0.45
Saline matter	0.35
	100.00

Cane juice has a specific gravity of 1070 to 1090—10° to 13° Beaumé. It has been obtained as low as 1046, and as high as 1110, at 80° Fahr. It is opaque, frothy, and of a yellowish green. The green part may be filtered out, leaving a pale yellow fluid, which is almost pure sirup. The green scum consists of chlorophylle, cellulose, ligneous fibre, and albumen. Its analysis given by AVEQUIN is—

	Per cent.
Cerosie—a peculiar wax.....	50.0
Green matter	10.0
Albumen and ligneous fibre	22.7
Phosphate of lime	3.3
Silica	14.0
	100.0

A gallon of juice, weighing about ten and three-quarter pounds, contains about twenty-seven grains of this greenish scum.

MULDER believes that the light-colored sugars contain most cane-sugar generally. He also says that the many varieties into which sugars are divided in Holland are not well based.

MULDER gives the following analyses of several raw sugars:—

	Sugar.	Molasses.
Chloride of potassium	8.03	1.58
Chloride of sodium	15.46	25.87
Sulphuric acid	10.85	7.91
Silica	13.59	1.93
Ashes	1.33	3.60

A few, out of many analyses made by Dr. STENHOUSE of the ashes of the cane, may be given—

Silica	46.46	41.37	46.48	50.00
Phosphoric acid ..	8.23	4.59	8.16	6.56
Sulphuric acid ..	4.65	10.93	7.52	6.40
Lime	8.91	9.11	5.78	5.09
Magnesia	4.50	6.92	15.61	13.01
Potassa	10.63	15.99	11.93	13.69
Soda	—	—	0.57	1.33
Chloride of potassium.....	7.41	8.96	—	—
Chloride of sodium	9.21	2.13	3.95	3.92
	100.00	100.00	100.00	100.00

Refuse of sugar has been analyzed by—

	Prof Johnston.	Dr Anderson.
Water	60.26	48.41
Organic matter—refuse blood and sugar	20.77*	39.10*
Phosphates of lime and magnesia	8.67	3.97
Lime	3.55	3.41
Magnesia	—	0.19
Common salt sulphates of potassa and soda	0.77	1.61
Insoluble silicious matter and sand	5.98	3.23
	100.00	100.00
* Containing ammonia	1.06	2.23

Blood is now less used, and a refuse like the above would not now be easily obtained.

The feculencies of the sugar obtained by defecation, without the addition of lime, or indeed of anything but

	Water given off at 212°.
Five kinds of candy sugar	0.011 — 0.475
Four kinds of white sugar	0.071 — 0.100
Four kinds of common sugar	0.121 — 0.225

It is found that sugar which is brought over in iron vessels, frequently oozes out and attacks the iron, doing injury to the vessel. Iron is rapidly dissolved by sugar. The sugar may become a little acid and then attack the iron, but it soon throws it down again as an oxide, as Dr. GLADSTONE has observed, and thus a small amount of sugar destroys a large amount of iron. Dr. GLADSTONE obtained the following compound:—

	Found.	Calculated.
Protoxide of iron	17.20	17.39
Sugar	82.80	82.61

Sugar readily decomposes a sesquioxide of iron in solution into a protoxide. Dr. GLADSTONE did not find that zinc prevented the oxidation of the iron. Zinc itself is not easily separated from sugar. Copper is scarcely acted on by sugar, but the oxide is dissolved, and lead is dissolved in no small quantities. This corroding power is not known to belong to pure crystallizable sugar, and the experiments of the above chemist must be taken as referring to the molasses, *et cetera*, united with it.

From the analyses on page 972 may be learned the absolute necessity of permitting the cane to attain its full growth and maturity before being cut for the extraction of its secreted sugar; and further, that in the system of manufacture in some cases adopted, the exhaustion of the cane is so imperfect as to leave fully one-half or three-eighths of its juice in the straw; thus, at the very first outset, causing a loss to the planter or sugar-maker of about one-half the quantity which the cane contains. When the other defects of the manufacture are considered as tending to convert the crystallizable into uncrystallizable sugar, producing fermentation and

water, were found by Mr. THORNTON J. HERBERT to contain 13.574 parts of a lb., composed of—

	Per cent.
Water	40.44
Organic matter	37.48
Carbonate of potassa	10.14
Sulphate of soda	6.60
Chlorides of sodium and potassium	12.77
Carbonate of lime and some carbonate of magnesia	3.34
Sulphate of lime	1.24
Phosphate of lime and some phosphate of magnesia	2.76
Phosphate of iron and alumina	1.52
Silicious residue insoluble in acids	3.84
	100.00

The dry substance contained 5.42 per cent. of moisture. Undried

The prepared sugar is very pure. MULLER found in one hundred parts of dry sugars—

	Ashes.	Grain-sugar.
.....	0.0 — 0.104	0.132 — 0.142
.....	0.03 — 0.735	0.134 — 0.250
.....	0.052 — 0.152	0.230 — 0.365

oxidation, the clue to the enormous waste in the manufacture of sugar is at once obtained. These losses may be grossly set down as being due—

To imperfect extraction of the juice	45 to 50 per cent.
To transformation to uncrystallizable sugar, <i>et cetera</i>	12.5 to 15 ..
Loss of crystallized sugar	57.5 to 65 ..
Balance, or quantity of sugar obtained	42.5 to 35 ..

2. *Extraction of the Juice.*—The sugar exists in the cells of the cane in the state of solution, which constitutes the juice or sap of the plant. Analyses have shown that the quantity of juice and its richness in sucrose, are variable to some extent; but on an average the per-centage of sugar amounts to seventeen or eighteen parts in good cane. The following additional analyses indicate an average composition—

	Centosimally.		
	From Martinique, by Peligot.	From Guadeloupe, by Dujuy.	From Cuba, by Casassa.
Water	72.1	72.0	68.7
Sugar	18.0	17.8	17.7
Ligneous matter	9.9	9.8	16.4
Salts	—	0.4	—
	100.0	100.0	100.0

Sueh also is the average composition of the cane of the third, fourth, and succeeding years' growth from the parent stock, as shown by PELIGOT's researches on this subject. HERVEY examined two specimens of sugar-cane of Guadeloupe, and the megass which they yielded. The samples were grown on two different soils—No. 1 being produced by a dry, calcareous, and elevated one; and No. 2, by a low soil in the neighborhood of volcanic eruptions. The following are his results calculated without water:—

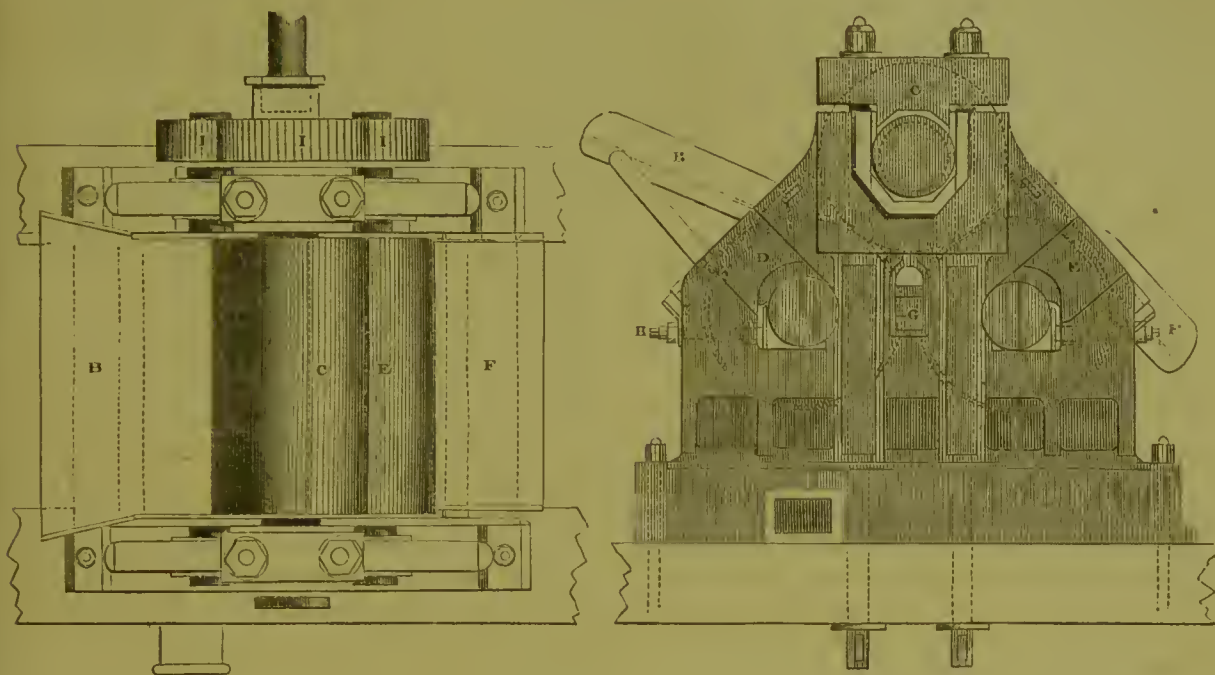
	No. 1.		No. 2.	
	Sugar-cane.	Megass or straw.	Cane Sugar.	Megass or straw.
Sugar	61.6	22.5	67.0	29.2
Extractive matters	0.3	—	0.3	—
Wax	0.9	1.8	1.2	1.6
Soluble salts	0.3	1.8	1.2	2.4
Insoluble salts	1.0	—	1.3	—
Ligneous matter	32.6	73.9	28.9	66.8
Loss	0.3	—	0.1	—
	100.0	100.0	100.0	100.0

The saccharine liquid is extracted from the cane by pressure. The sugar-mills employed for this purpose are chiefly three, namely, the horizontal and the vertical roller mill, and the hydraulic press. The latter,

however, has not received general adoption. The accompanying woodcut—Fig. 554—shows the construction of horizontal sugar mill.

The vertical mill, in which the crushing cylinders

Fig. 554.



are placed vertically, has the advantage of being more easily cleaned; but it is less easily fed, and is more costly in its construction. A great deal depends upon the right adjustment of the distances of the three rollers, a too near approximation causes, on the one hand, an increased expenditure of force in the working of the mill, and on the other, a too great distance allows a portion of the juice to escape extraction, and to be carried off in the megass. The distance between the feeding roller and the upper one is about half an inch; the delivering roller is still closer to the upper one. In feeding a horizontal mill, the canes are cut into lengths of about three feet, and so spread upon the feeding board that these may overlap one another as little as possible. Mills have also been constructed with five and with four rollers. When five rollers are employed three are placed below and two above. A five-roller mill is said to extract ten per cent. more juice from the cane than a three-roller one; but the megass is thereby much broken, and a much greater expenditure of mechanical power is required to work the mill. In the four-roller mill, where two rollers are placed below and two above, while a greatly superior amount of juice is obtained, the expenditure of force is said to be not much greater than in the ordinary three-roller mill; hence it is probable that the four-roller mill will gradually supersede those now generally in use.

Some years ago a method was patented by Mr. MICHEL for extracting the sugar from cane without the use of the mill; it was proposed to cut the canes into thin slices and treat them with lime water. The object of this was to render the nitrogenous constituents of the

cane insoluble. On treating the so-prepared canes with water, a sirup is obtained of a purity much greater than that obtained directly by mechanical means. Probably the mechanical difficulty experienced in slicing the canes has prevented the adoption of this method. The following are the experiences of Dr. EVANS—given in the *Sugar Planter's Manual*, published in 1857—in regard to the advantageous working of a sugar mill:—1. The rollers should be approximated as closely as the work which they have to perform will admit of. In mills in which the rollers observe a vertical direction, the space between the first and second should scarcely, if at all, exceed a quarter of an inch, whilst a distance of one-sixth of an inch is the most that should be allowed between the second and third. When they are placed horizontally, the upper one should be distant a space of one-fifth to a quarter of an inch from the two lower. 2. The velocity of the rollers should be rendered as uniform as possible, not by diminishing the amount of the motive power, but by a carefully regulated supply of canes. 3, 4. The megass should be invariably repassed between the rollers so as to extract as much as possible the juice which still remains in it. When canes are rich, and their juice of considerable density, the megass should be sprinkled with a little water, or, where it is practicable, exposed to the action of steam before it is submitted to the pressure; but when the canes are large, green, and watery, this may be dispensed with.

The amount of juice obtained from the cane is not always a criterion of the comparative yield in sugar. The drought or humidity of the season preceding the cutting of the canes determines the presence of a less

or greater amount of water in the cane, while the quantity of sugar remains for a time unaffected. Between moist and dry seasons, and thorough and imperfect crushing, the yield of juice may vary from fifty to seventy-five per cent. of the weight of the canes employed.

The following table shows the proportions of the solid constituents—other than sugar—in cane juice. The relation of these amongst one another is probably pretty constant, although the quantity of sugar and of water may vary much with the age of the plant and the season at which the juice is extracted.—*Ure*.

One hundred parts of solid constituents contain—

Sulphate of potassa,.....	11.3
Phosphate of soda,.....	10.2
Chloride of potassium,	5.3
Acetate of potassa,.....	40.6
Acetate of lime,.....	22.9
Silicic acid,.....	9.7

100.0

The methods employed in Hindostan and Ceylon for the extraction of the sirup or *goor* from the cadgoolee and other species of indigenous cane are so imperfect as to require no special description.

Captain MARGETSON, R.N., has proposed to cut the cane in pieces, and dry it as beet-root is dried, sending the substance home for the extraction of the sugar. This is a very promising field of inquiry.

3. *The Purification of the Sirup*.—The removal of impurities from the juice, as it is delivered from the mill, may be divided into two processes, defecation and clarification.

The crude cane juice contains, besides sugar and water, the impurities—earthy insoluble particles, fragments of the crushed cane or megass, albumen, caseine, wax, soluble coloring matter, and soluble salts. The coarser of the insoluble particles are sometimes removed mechanically previous to the process of defecation. But certain of the nitrogenous impurities of the crude juice if left in contact with the sirup speedily determine its fermentation, thereby occasioning loss in sugar, and owing to the subsequent conversion of the alcohol generated by fermentation into acetic acid, causing the corrosion of the metallic portions of the machinery, and the introduction of metallic acetates into the sugar. It is of the greatest importance that the process of defecation, whereby the nitrogenized compounds are removed, should follow with as little delay as possible upon the extraction of the juice. For this reason the storing of the sirup in tanks until a sufficient quantity is obtained for purification, is to be reprehended. The first filtration also should, for the same reason, be performed as rapidly as possible. This filtration is effected through a double sieve, the metallic meshes of the first sieve being about one-twelfth, those of the lower about one-thirtieth of an inch asunder. The sirup is run from these sieves, or directly from the crushing mill, through a wooden gutter lined with lead to the clarifiers. These are a series of copper cauldrons capable of holding from three thousand to four thousand gallons each. The bottoms of the clarifiers are usually concave, being bulged inwards from below.

Each cauldron is provided with a separate fire, the flues from which run into a common chimney, and each fire is provided with a separate damper for regulating or stopping the draught.

Defecation.—When this is performed in the Colonies the sugar is boiled down from the strength of 10° Beaumé only to about 27° or 28°, which is the strength suited for hot filtration. When it is performed in England, the sugar is dissolved in water, so as to be of the strength of 27° Beaumé.

Lime is the agent most frequently employed in defecating the sirup; but considerable differences of opinion exist concerning the best method of its application. The lime should be thoroughly burned and quickly slaked with hot water, enough water being added to give the consistence of a cream. This should be then filtered through a fine wire sieve in order to remove silicious particles and fragments of unslaked lime or unburned limestone. Some sugar manufacturers adopt the following process:—When the sirup in the clarifiers has attained the temperature of 130° Fahr. successive portions of the cream of lime are added until the acids in the sirup—acetic and lactic—have been completely and exactly neutralized, which is shown by its neutrality to blue and red litmus paper. The mixture of sirup and lime is thoroughly incorporated with an oar, and the whole left to digest for about a minute. The portions of cream of lime successively added to effect neutrality should not contain more than about four ounces of solid lime per gallon. The product so obtained is run off through a stop-cock in the clarifier, either through bag filters or through charcoal filters, subsequently to be described. In the more common process of defecation, however, after neutralization by cream of lime, as above described, the heat is urged until a temperature just below the boiling point of the sirup is reached. A thick scum is then formed upon the surface of the sirup, and the clarification is judged complete when this scum breaks and a white froth appears in its interstices. In all cases an excess of lime is to be avoided, partly because nitrogenous matter, upon the removal of which, from an acid solution by heat and lime, the clarification in a great measure depends, is redissolved by an excess of this agent, but mainly because of the destructive action of caustic earths on sugar. If, however, an excess of lime has been added, it may be remedied by the addition of small quantities of a solution of alum. When this salt is added to any alkaline solution with excess of lime, its alumina is precipitated and rises with the same, fixing a portion of the coloring matter of the sirup at the same time, and thus assisting in the clarification. Of the simultaneous products found in this reaction, *videlicet*, sulphate of lime and sulphate of potassa, the first is in a great measure insoluble and rises with the scum; the second, however, is soluble in the sirup, and cannot be subsequently separated from it: and this is the only drawback in the employment of alum to neutralize overlimed sirup. Sulphate of alumina, however, is not subject to this disadvantage, and may, therefore, advantageously replace alum in the neutralization of overlimed sirup.

Other substances have been employed for the defe-

cation of cane juice, of which the principal are bullock's blood, nut-galls, sulphate of zinc, alum, sulphate of alumina, sulphuric acid and lime, and subacetate of lead. As bullock's blood is almost exclusively employed in the defecation of beet-root sugar, its application will be described under that head.

Nut-galls.—After the clarification by means of cream of lime of four hundred gallons of sirup has been effected, the temperature is raised to 150° or 160° , and a decoction of nut-galls is added, formed by digesting two ounces of the bruised galls in half a gallon of boiling water. The mixture is stirred for two or three minutes with an oar, boiled and strained through bag filters.

Sulphate of Zinc.—Twelve ounces of sulphate of zinc are added to a clarifier of three hundred gallons. The sirup is then neutralized with cream of lime, boiled and filtered.

This process has not been used, as it is difficult to remove the taste of the zinc.

Alum.—Four pounds of alum in solution are added to a clarifier of three hundred and fifty gallons; as it begins to get warm the heat is rapidly raised to 140° , and the sirup neutralized with cream of lime.

Alum should never be used, as it introduces salts of the alkalies, which cannot be removed.

Sulphate of Alumina.—A pound of sulphate of alumina is added to every hundred gallons of juice, and the whole quickly neutralized with lime and filtered as before; still not of much value.

Ammonia has been proposed as an addition to sugar, especially to beet-root juice; but its value has not been shown.

Alumina and Sulphate of Lime.—The alumina obtained from two pounds of alum by precipitation along with sulphate of lime, by means of carbonate of lime in suspension, is washed by decantation and added to one hundred gallons of cane juice. When the temperature of the sirup has reached 150° , lime is added to neutralization and the juice is then filtered.

Sulphuric acid diluted with thirty times its volume of water is added to the sirup—for three hundred gallons of the latter, two fluid ounces of sulphuric acid are employed—at a temperature of 120° ; four ounces of lime are then added, and when the temperature reaches 170° , the sirup is neutralized with more lime and filtered.

The value of this method is extremely small.

Subacetate of Lead.—It has been proposed to effect the defecation of the sirup by the successive employment of subacetate of lead and phosphate of lime. Subacetate of lead has the power of throwing down the whole of the coloring matter and other organic foreign substances present in the sirup. But the subsequent separation of the lead which is in solution by phosphate of lime, is either not perfect in the presence of sugar, or requires more delicate manipulation and greater care than can be usually looked for in sugar manufactories. The deleterious action of repeated though very minute doses of lead on the system has prevented its employment as a defecating agent.

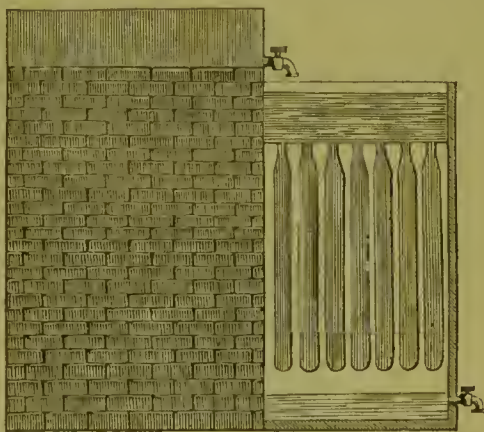
Dr. SCOFFERN precipitates the lead by sulphurous acid, and by this means it is found that he can remove

it all; but the dangers attending the use of lead are so great, that his process, although beautiful when done well, and perfectly capable of being done well, has been discouraged if not prohibited, and the plan will therefore probably be abandoned. Man's constant accuracy cannot be trusted. Tin has been tried, but is not practically found useful.

When the scum has risen to the surface, and the clear sirup is seen through its cracks, the approach of which point is usually judged of empirically by the thickness of a portion of the sirup removed from the clarifier, and by the equalization in size of the bubbles formed in the liquid, the defecation is complete. The defecated sirup is then removed from the scum by tapping, or the latter is removed from the sirup by skimming, in both cases sufficient time being allowed for the heavier portions of the scum to subside. As the scum always contains a considerable portion of sirup in its pores, it is generally submitted to pressure in a simple lever press, and the extract added to the liquid which has been tapped off. Fig. 555 shows the usual form of the clarifier.

In those countries where fuel is cheap, and especially in those manufactories where steam is employed, either as a motive power for the mill, or the vacuum pan—afterwards to be described—or for other purposes,

Fig. 555.



the heating of the clarifier is sometimes effected by means of steam. It is clear that as the temperature requisite for boiling in the open air is above that of boiling water, the steam by which it is effected must be either overheated or high pressure steam. And as in most sugar growing lands fuel is scarce, and as a great use of fuel attends the application of overheated steam, high-pressure steam is employed. This is usually conveyed by a copper worm through the clarifier, the steam passes downwards round the spirals of the worm, and the condensed water is discharged under pressure.

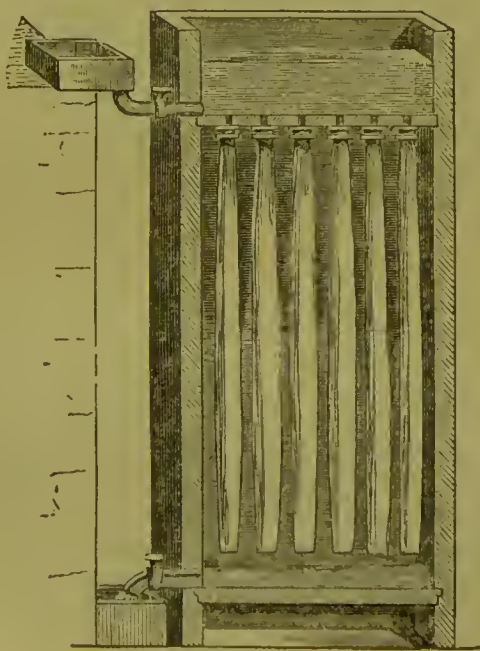
Simple Filtration.—The process of defecation always leaves impurities in the sugar, either in the form of suspended scum, or when filtration is not performed previous to the defecation of the mechanical impurities formerly mentioned. In all cases it has now to undergo another filtration.

It is usual to run off the sirup at once from the clarifiers upon the filters, and the preceding diagram shows the simplest arrangement for this purpose. The matter of the filter is always cotton. Woollen textures are rapidly destroyed by the alkaline nature of the scum. The forms given to the filters are chiefly two—the leaf-filter of LOVERING and the bag-filter of TAYLOR.

The leaf-filter is composed of a series of cotton bags stretched over thin quadrangular frames, which keep the sides of the bags apart, and cause them to present a smooth even surface instead of folds, thus greatly facilitating the operation of cleaning, when it has to be performed. These frames are arranged side by side in a box, and the juice which filters from without inwards, escapes by a hole in the bottom of the frame. The juice is poured into the box outside of the frames, and the filter, therefore, is not clogged by impurities as readily as TAYLOR's filter, in consequence of which it works more rapidly and does not require to be cleaned so often.—*M^cCulloch*.

TAYLOR's bag-filter—Fig. 556—consists of a number of cotton bags about two feet in length and a foot in diameter when fully extended. Into their narrow mouths the nozzles of the tubes pass which deliver the sirup. The bags are fastened on the nozzles by means of a sliding ring. Each bag is inclosed in a cylindrical one of canvass about four inches in diameter, the object of which is to prevent the swelling out of the interior cotton filter. In such a filter of course the interior bag is much folded; nor can it in this state present the same amount of filtering surface as it would were it fully inflated. It may indeed be questioned whether

Fig. 556



with tolerably clean sirup such a folded filter offers much advantage above a filter of the size and shape of the exterior canvass bag.

When the leaf or bag filter has become choked it

must be washed; this is sometimes done by machinery. The use of very dilute hydrochloric acid or of acetic acid facilitates the washing, by dissolving the fine scum. But the first acid at least, however dilute, weakens the cotton fabric when often applied, and the presence of every acid should, when possible, be avoided in every process of sugar manufacture; because the vinous fermentation to which all saccharine liquids are liable is found to be facilitated by the presence of any acid.

Charcoal Filtration.—The previously described processes of filtration and defecation effect the removal of the mechanical impurities in the sirup, as well as those albuminous and nitrogenous substances which are solidified by the heat of the clarifiers, and removed in the scum which is formed in them. But besides such impurities, the juice of the sugar cane contains various coloring matters, whose chemical nature has not been examined, and which are not removed either by filtration or defecation—except where, in the latter process, subacetate of lead is employed. As these coloring matters do not separate by the further evaporation of the sirup, but obstinately remain with it, a further process of decolorization is necessary before the final evaporation is effected. Animal charcoal is the agent employed for this purpose. When the bones of animals are subjected to dry destructive distillation, without access of air, the residue consists chiefly of carbon, and the phosphates and carbonates of lime, with a little of the same salts of magnesia. Such charcoal possesses pre-eminently the power of removing many organic substances from solution when brought into prolonged contact with the liquids which contain them. Thus strychnine when in solution is removed by agitation with animal charcoal. The decolorization of sirup depends upon the same power of animal charcoal. Animal charcoal or bone-black, in removing coloring matter from sirup, undergoes no profound change. It appears to act by a species of superficial affinity; that is, as far as the process can be followed, an affinity that pervades the surface of every one of the minute pores of the charcoal, rendering the actual superficies enormous. But although the charcoal thus remains unchanged, its decolorizing power is so far limited, as when its surface becomes too thickly covered by the coloring matter it withdraws, a charcoal surface is no longer presented to the liquid.

The bone-black preferred by sugar manufacturers for the decolorization of sirup is that obtained from the larger bones of animals—as the thigh and shoulder bones of oxen. This variety is generally not only more compact than that obtained from the smaller bones, or from the bones of smaller animals, but appears to possess a specifically greater decolorizing power. Such bones after burning are reduced to a coarse powder, the grains of which are about the size of small peas. In some manufactories, however, where the process of defecation and decolorization are united, and where powdered bone-black is added to the sirup in the clarifier, the bone-black is employed in a finer state of division, the grains being then of the size of those of the finest gunpowder. But as in this method the bone-black

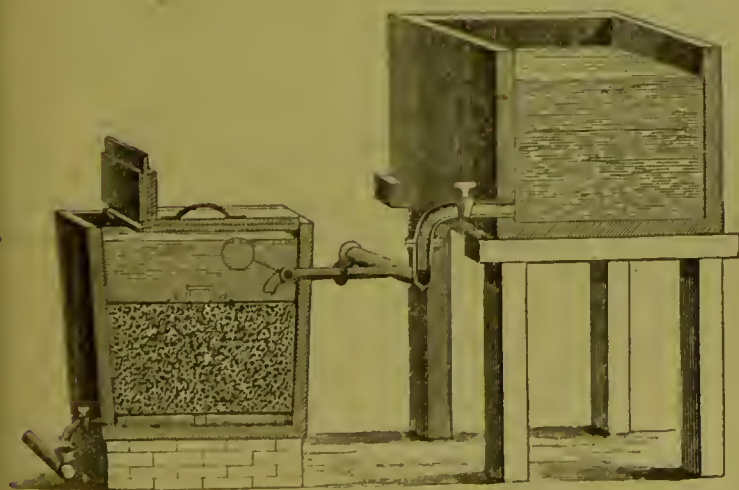
employed is thrown up with the scum in the clarifier, mixed with the salts of lime and other feculences from which it cannot be separated, it is lost, and consequently the application of bone-black in the clarifier is seldom adopted. The decolorization by filtration through bone-black is generally effected immediately after the filtration through the cotton filters above described. The following description of the two kinds of bone-black filters most frequently employed abroad, but now scarcely used here, is from R. S. McCULLOCH's report.

Dumont's filter consists of a wooden box of the form of a four-sided truncated pyramid with a double bottom. The inner bottom is a metallic plate pierced with numerous holes; upon it a cotton cloth is laid, and coarse-grained animal charcoal moistened with water is then spread layer by layer; each layer being rendered of uniform thickness, and packed or pressed closely together by means of a sort of trowel. When the bone-black has been thus formed into a compact bed or stratum of about fifteen or eighteen inches in thickness, and within five to ten inches from the top of the box, it is covered with another cotton cloth, and with another metallic plate pierced with holes. The object of the second cloth and metallic cover is to collect any substances which would otherwise obstruct the interstices of the superior stratum of the bone-black—an inconvenient accident which is easily prevented by the use of such a cover, and this cover is readily exchanged for another, should it become itself obstructed. The superior cover is only of use when the previously described filtration through the cotton bag or leaf filter is omitted.

It is important, in order to avoid false passages, that the juice should be constantly at the same level of about three or four inches above the cover of the bone-black. This is accomplished by means of a self-regulating cock.

To facilitate the action of DUMONT's filter—Fig. 557

Fig. 557.



—the bone-black must be perfectly free from fine powder, which would obstruct the passage of the sirup, and thus retard its flow. To render it so it should be carefully sifted each time after revivification.

PEYRON's filter is another form of metallic filter

to be used like that of DUMONT's with coarse bone-black. It is intended, however, to act continuously and without renewal of the bone-black. This filter is cylindrical, in height eight feet, and in diameter thirty-nine inches. The top is closed with a perfectly air-tight cover, and the vacant space of the double bottom communicates by a tube and cock with the top of a second and smaller filter, so that the sirup which has filtered through the first passes through the second, from which, in like manner, it proceeds through a third. The closed top permits the use of hydrostatic pressure to increase the rapidity of filtration, and the juice enters the first filter for that purpose by a tube from a reservoir above. The double bottom of each filter of the series is also provided with another outlet and stop-cock to permit the fluid contents to be drawn off at any time, if desired.

The filters of PEYRON, like those of DUMONT, are charged with coarse bone-black, carefully compressed in layers; after which the fine powder is washed out thoroughly with water, and when this flows perfectly clear the sirup is allowed to pass into the filter, and to remove the water by *displacement*. As soon as the water which escapes from the double bottom is sweet to the taste, it is collected in the reservoir to be evaporated. After the sirup ceases to flow freely, hot water is used to displace that portion absorbed by the bone-black; and as soon as the density of the escaping liquid becomes feeble it is no longer collected. The hot water is then allowed to flow through the filters until they are washed perfectly. Fermentation soon commences in the filter by reason of the dilute sirup and nitrogenous impurities absorbed by the bone-black; and after twenty-four hours, when the fermentation is considered complete, and the impurities taken up by the bone-black are thereby destroyed, the filter is cleaned to prepare it for work a second time, by first passing through it for half an hour a jet of high-pressure steam, and subsequently washing it thoroughly with hot water.

Another form of filter somewhat similar to PEYRON's is as follows:—A series of four cylindrical boxes, provided with perforated false metallic bottoms are connected together as before with stop-cocks in such a manner that each may be removed without disturbance of the rest. If they are all charged with fresh bone-black, and the sirup is run through until it begins to become colored, it follows that the charcoal in the upper boxes must have lost its decolorizing power to a greater extent than that in the lower ones. The highest box is therefore removed; the next highest becomes now the highest, the third becomes the second, and so on—a box of fresh charcoal being introduced below. In this manner the filtration may be carried on with but little interrup-

tion for any length of time. To insure the uniform distribution of the sirup upon the upper layer of the box, a mechanical contrivance is sometimes employed. This is of the form of a horizontal tube, perforated with holes throughout its length, but closed

at its ends, and capable of revolving with facility about its centre. The passage of the sirup through the tube and through its orifices determines the revolution of the tube about its axis, and the consequent distribution of the sirup upon its surface.

The filters on the Continent are still frequently of this kind, but such are seldom used in England, where it has been found economical to use them of enormous size, being about thirty feet in height, and four to eight feet in diameter. A filter like this contains about twelve tons of animal charcoal. Charcoal is expected to purify, on an average, an equal weight of fine, or twice its weight of *seconds* sugar.

The same bone-black may be employed any number of times, provided the substances which it has withdrawn from the sirup be removed. This is sometimes done by allowing them to ferment, as in PEYRON's filter; but more frequently by simple rekilning. The kiln made by G. F. CHANTRELL of Liverpool for the revivification of the bone-black is seen in Fig. 558. Those of PONTIFEX and WOOD and others are under the article *Charcoal*.

Perhaps no part of a sugar refinery is more important than the burning of the charcoal or bone-black. This is generally used in small pieces, the largest about the size of a half pea, and slightly elongated in the direction of the length of the bone from which they are formed. It was at one time usual to grind the charcoal to dust, but this habit is now almost entirely given up. When fine the sugar does not run so rapidly through the filter, and it is not mixed with so much facility or so much convenience; besides, it is not so easily burnt or revived. In general, too, refiners object to the very fine charcoal, and either drive it off by blowers when the charcoal is dry, or remove it by lixiviation. It is sold to the manufacturers of superphosphate of lime at about five to six pounds per ton.

By means of flues a series of brick walls about eight feet in height are heated red hot. The walls are in pairs, each two of which are about eight inches apart. The space between each pair of walls is completely filled with the spent bone-black, the pile of which rests upon the ground. The upper end of each vertical layer forms a part of the heap of spent bone-black, which therefore covers the top of all the walls. When the walls have reached a red heat, and remained for a quarter of an hour at that temperature, enough bone-black is raked from the lower ends of the columns to cause each pile to sink about six inches. The heap of charcoal at the top supplies each column as it sinks. The same process is repeated, so that every portion of the bone-black gradually falls between the red-hot walls, and is raked out from below. The column of bone-black is sufficiently compact to prevent the ingress of much air, and the consequent burning of the carbon which would thence result. The red-hot charcoal as it is raked from below is thrown into metal boxes to cool; it is then sifted to remove the powder which has been formed, and is fit for use again.

The animal charcoal effects not only the separation of the coloring matters, but also that of the excess of

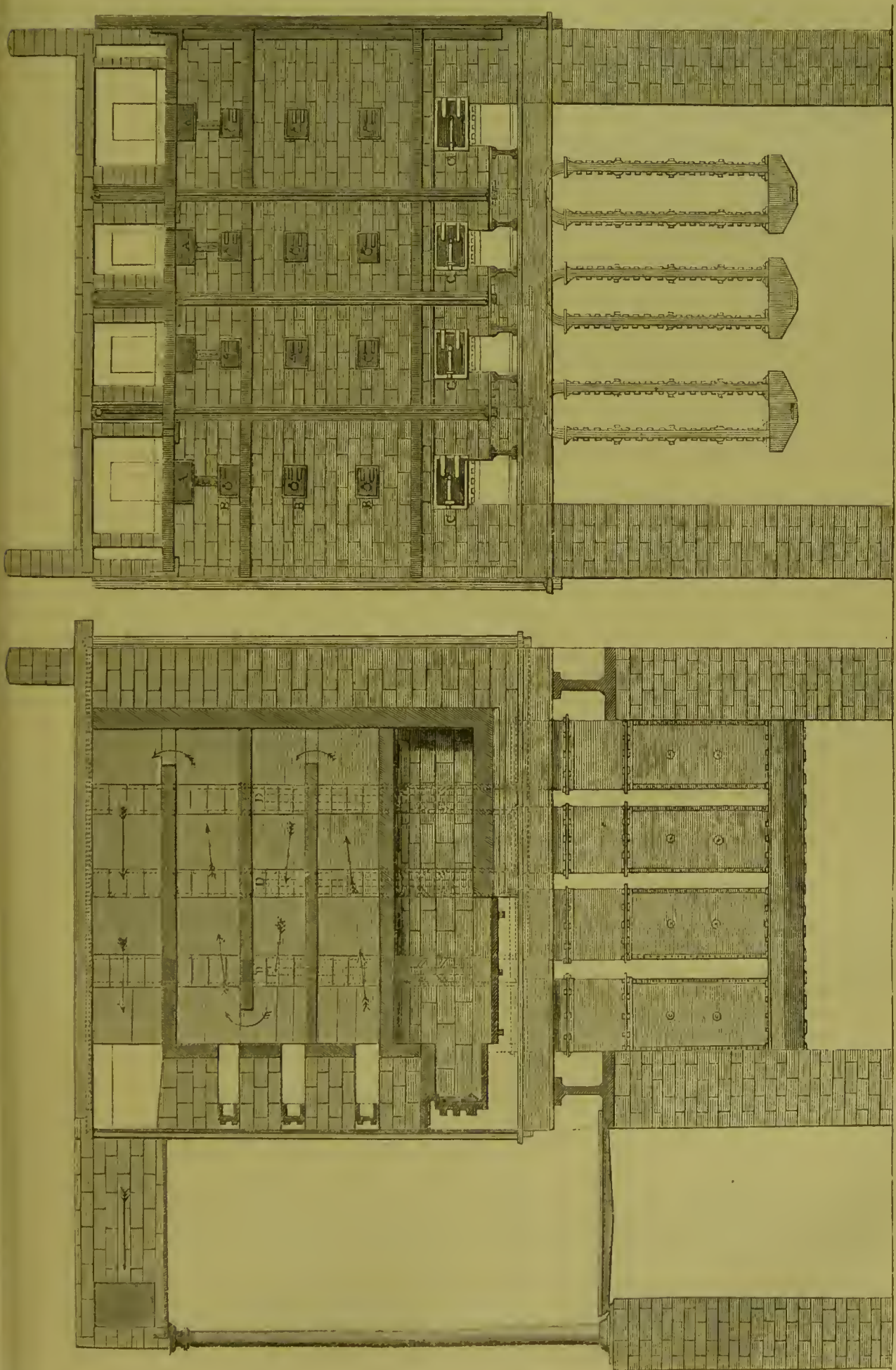
lime present in the sirup, and in the vivification of the spent bone-black this lime of course remains behind. It is proved, however, that the lime does in no way impair the decolorizing power of the charcoal. It has been supposed that such lime forms phosphate of lime with the phosphoric acid contained in the coloring matters of the juice, and thus on their carbonization gives rise to a charcoal having the same decolorizing power as the original bone-black derived from animal organization. But the gain from this must be trifling.

The kiln made by Mr. CHANTRELL of Liverpool is now becoming more and more extensively used. It is of firebrick. Fig. 558 shows the kiln in elevation. Above is a hot floor, on which the charcoal is dried before it is strongly heated. The hot floor is seen also in the longitudinal section, where it is shown to be heated by the flux which comes from the furnace on its way to the chimney. The kiln represented here contains twelve chambers for the charcoal, each two feet long and three inches broad. In front there are three, and in the side view four behind each furnace door. These chambers or slides receive the charcoal at the top after drying, and being filled up with it and heated to redness, all the organic matter in the charcoal is destroyed. When this is done, or in about forty minutes, the slide at the bottom is removed, and the charcoal falls into either iron vessels somewhat narrower than the red-hot chambers. Each chamber divides into two columns which are exposed externally to the air, and allow the charcoal to become black, removing all fear of burning or uniting with oxygen, when it arrives at the measuring box at the bottom.

The elevation shows the furnace doors, and above them three doors to open into the flues which circulate among the chambers, as seen by the arrows in the longitudinal section. Each door has a spy-hole, which is usually kept covered. It is used to inspect the condition of the flue as to heat and cleanliness. Three perforations between the furnaces at the top are holes for conveying away the gases which are generated. On the elevation the iron braces are seen at the side and between the kiln doors. This kiln is said to require much less coal than the iron pipes, saving, according to some, seventy per cent. Certainly we know the greater conducting power of heat possessed by iron. For this reason it is used for cooling, whilst bricks are used for containing the heat. Some persons expose the charcoal to the air some days before using it, believing that it is improved thereby. Many people carefully avoid using it warm. There may be a true foundation in these customs, but some careful observers have looked in vain. It is common in London for the sugar refiners to have no charcoal of their own, but to obtain it from the charcoal burners ready for use, returning it again when it is used. For the use of a ton they pay thirty-five shillings. This may suit the London method of filtering, which is slow; but it will not suit the Lancashire method of rapid filtration. The first may last a week or more; the second only two or three days.

The burning of charcoal may become a great nuisance to a neighborhood, if not watched. The sugar sometimes left in it is decomposed, and a very

FIG. 558.



pungent vapor is sent off, whilst salts of ammonia also are found in it. To avoid these evils, it is needful to wash the charcoal with great care as soon as it has done its work. Charcoal usually contains seven or eight per cent. of carbon, and when this is removed the charcoal is of little value. It is easily removed if heated in contact with air. Its value is about thirteen pounds per ton, or perfectly dry about fourteen pounds. There is a large amount of soft charcoal, which readily goes into dust; hard charcoal is more valuable.

Charcoal is sometimes allowed to ferment, in order to free it of its acquired impurities. This fermentation generally means merely the action of a weak acid—dilute muriatic. It is useful in beet-root establishments, on account of the large amount of lime needed to throw down the substances in the juice. In the sugar, or in the juice of the sugar-cane, no such excess of extraneous matter exists, and no large excess of lime ought to be used. Such at least is the opinion of the writer, and his experience has not been small. Charcoal itself is like a cavern of mysteries, the more it is studied the more wonderful are its secrets. Science has not yet approached the difficulties as seen in practice, and partly overcome.

A mode of renewing the charcoal, by passing heated steam through it, is in actual use in France. The charcoal need not be taken from the filter, but constantly renewed *in situ*. The process may be conducted for a long time, but as far as inquiries have extended, the plan is actually more expensive than burning in kilns.

No substitute for animal charcoal has been found to approach it in value. It must be hard enough to retain its form after years of use and frequent movement. It must also be porous, and must contain fully seven per cent. of carbon.

The sirup after passing through the bone-black filter is in the state of maximum purity. The subsequent processes of the sugar-maker consist in the removal of the water. This is effected by evaporation.

4.—*Evaporation.*—The modifications of the method employed in evaporating are four:—

1. Evaporation assisted by artificial currents of air.
2. Evaporation by fire in open or closed vessels.
3. Evaporation by steam-heat in open or closed vessels.
4. Evaporation by steam-heat *in vacuo*.

The sirup after treatment with bone-black is run into the evaporating or concentrating pan; the shape of this is various according to the method of concentration to be employed. In a patent taken by G. KNELLER the heated sirup in the pan was submitted to the action of currents of cold air, which was blown through it from a perforated copper pipe immersed in the sirup. The currents of air performed the double purpose of subduing the heat of the sirup and of removing the vapor of water which was formed. The apparatus employed by M. HALLÉTE was based upon a similar principle. It consisted of two concentric copper cylinders, so closed at top and bottom with circular discs as to form a cylindrical jacket. This jacket turned upon an axis in an inclined direction; and was heated by a current of steam. The sirup was allowed

to fall upon the surface of the internal cylinder at its upper end. The heated column of air and aqueous vapor in the internal cylinder determined an upward draught, which carried off the vapor; while by the rotation of the jacket the sirup was spread by centrifugal force into a uniform film upon the internal cylinder, thus exposing a great surface to the drying current. M. CHEVALIER devised an apparatus which combines the principles of those of KNELLER and HALLÉTE. The sirup in the evaporating pan is heated by the action of a coil of steam-pipe immersed in it. The pan is provided with a false perforated bottom. Air, which has been heated by passing through pipes heated in a separate vessel, is blown by machinery into the pan below the false bottom. It ascends and escapes as bubbles through the perforation of the bottom, carrying with it the aqueous vapor in its passage through the sirup. This apparatus is said to be very effective and rapid in its action, but the fuel required for its working is great. A simpler and equally effective plan is that proposed by Mr. GADDESSEN, which is thus described by Dr. EVANS:—

This gentleman's apparatus consists of an iron or copper pan, having nearly the form of the half of a hollow cylinder, in which is placed a drum or wheel adapted to the shape of the vessel, and formed of a number of metal rods so arranged that the evaporating surface given to the sirup is increased as much as possible. The wheel, half its circumference being immersed in the liquid, is kept constantly revolving, so that by exposing fresh portions of the heated sirup to the action of the atmosphere at each succeeding revolution, the evaporation of the aqueous particles is rendered more rapid than it otherwise would be, while the temperature is, at the same time, in a corresponding degree reduced. The time required to take off a skin in a pan containing one ton of sugar varies from two and a half to four hours, and the temperature of the sirup ranges from 150° to 180°. From the principles upon which this method of concentration is based it is evident that its successful working will depend upon the degree of dryness of the atmosphere, and upon the rapidity with which the air passes over the surface of the sirup. The apparatus should therefore always, when it is practicable, be placed at the windward side of the boiling-house; at all events it should be beyond the influence of the vapors which arise from the evaporating vessels.

Some manufacturers assert that the revolution of the drum is apt to occasion frothing in the sirup, however pure the latter may be—especially, as is sometimes the case, if the rods on the drum are of wood instead of iron. The advocates of GADDESSEN'S pan, on the other hand, maintain that the frothing, when it occurs, arises from albuminous and other impurities in the sirup, and that it may be entirely prevented by the addition of one or two drachms of washed butter or a few drops of fresh olive oil—an addition which, in all sugar boiling, hinders the formation of permanent bubbles, and, in GADDESSEN'S process, allows the drum to be worked at a greater velocity, and the evaporation to be thereby accelerated without inconvenience.

When the water is expelled from the sirup by the simple application of heat to the evaporating pan, and without the aid of mechanical means to increase the evaporating surface of the sirup, the heat applied must be greater than when such helps are had recourse to, in order that the sirup may be concentrated in a reasonable time. For this reason, the evaporating pans must be so constructed and filled with the sugar as not to allow the parts of the pan above the liquid to become unduly heated, and to cause thus the caramelizing and blackening of the sirup. Great care must on this account be employed in the firing of such pans. Where open pans are employed, that is, where the sirup is boiled at the ordinary atmospheric pressure, the approach to sufficient concentration for removing to the crystallizing pans may be judged of either by the physical appearance which a portion of the sirup presents when removed from the evaporating pan, or by the temperature which the sirup assumes; for a sirup consisting wholly of crystallizable cane sugar and water, boils at temperatures which are higher, according as the quantity of water it contains is less. The examination of the physical appearances of the sirup for this purpose is called proof by touch. When the sirup is approaching concentration, it presents the following appearances in succession:—

1. A copper ladle dipped into it, inverted and withdrawn in such a manner that the edge of the ladle is horizontal, is covered with a layer of sirup of uniform thickness, which drains off, not in isolated streams, but, for some distance, in a continuous sheet. 2. On taking a pinch of the sirup between the fore-finger and thumb, and depressing the latter, the sirup separates, and the drop on the finger is nearly equal in size to that on the thumb. 3. By the separation of half an inch, a thread is drawn out, which finally breaks below, the end of the thread becomes hooked, and it rises slowly towards the finger. 4. The same thing occurs at a greater distance, the end of the thread is folded back, and gives to the thread the shape of a long ribbon or stick, which rises more rapidly than before. 5. After a greater separation of the fingers, the thread breaks, being very fine at the end, which turns aside and twists up like a corkscrew. It does not fold itself upon the rest of the thread as before, and the thread does not increase in volume, except by the cohesion, which draws the particle towards the finger, which is the only adhering point. A little more concentration prevents the thread from shrinking at all.

The proof by blowing is performed by dipping a perforated copper ladle—the holes in which are about one-eighth inch in diameter—into the sirup, and then, inclining its edge at an angle of about 45°, the workman blows strongly into the cavity of the ladle, whereon, if the sirup be well concentrated, bubbles are formed of half an inch in diameter on the other side of the ladle.

The following table shows the connection between the temperature of the sirup and the amount of water it contains for one hundred parts by weight of sugar. It shows, also, the degrees of concentration at which some of the above-mentioned terms are applied. The table is from DUMAS:—

Temperature. Fahrenheit.	Composition.		Name.
	Sugar.	Water.	
213·8	100	124·66	—
215·1	100	106·81	—
215·6	100	88·96	—
217·4	100	91·11(?)	—
219·6	100	53·26	—
220·1	100	47·26	—
221	100	41·63	—
223	100	36·00	Weak hook.
226	100	28·52	Thin thread.
231	100	25·05	Common hook.
233·6	100	18·84	Strong hook.
246·2	100	—	Ordinary bubble.
248	100	—	Perfect bubble.
234·5	100	—	—
239	100	16·29	—
251	100	—	Small fracture.
263·3	100	10·92	Large fracture.
270·5	100	—	Fracture on the finger.
271·4	100	—	—

It appears from this table that when the sirup has reached 248°, although water continues to be given off, yet the temperature sinks to 234·5°, after which it again rises. If there be no error in the observation, this is probably due to the formation of a definite hydrate of sugar, which requires a higher temperature for its decomposition; but that decomposition being once determined, the water expelled takes up the caloric as latent heat in its conversion into steam, thus depressing the temperature of the sirup.

The danger of caramelizing portions of the sugar, and thus impairing not only the beauty of the product, but, by the formation of noncrystallizable sugar, diminishing the quantity obtained, has caused sugar manufacturers to seek for means by which this evil may be avoided. The vacuum pan of HOWARD answers this purpose completely. It is universally employed in Europe, and to a large extent in the Colonies.

All liquids boil at lower temperatures when the pressure upon them is lessened. The pressure exerted by the atmosphere upon liquids in open vessels varies from fifteen to ten pounds per square inch. In a vacuum no such pressure exists, and, therefore, liquids boil at lower temperatures than in open vessels. HOWARD'S process for concentrating sirups consists in heating them in vessels from which the air has been wholly or partially withdrawn, that is, in more or less perfect vacua. The heat is applied to the sirup in the evaporating pan by means of a pipe containing high-pressure steam.

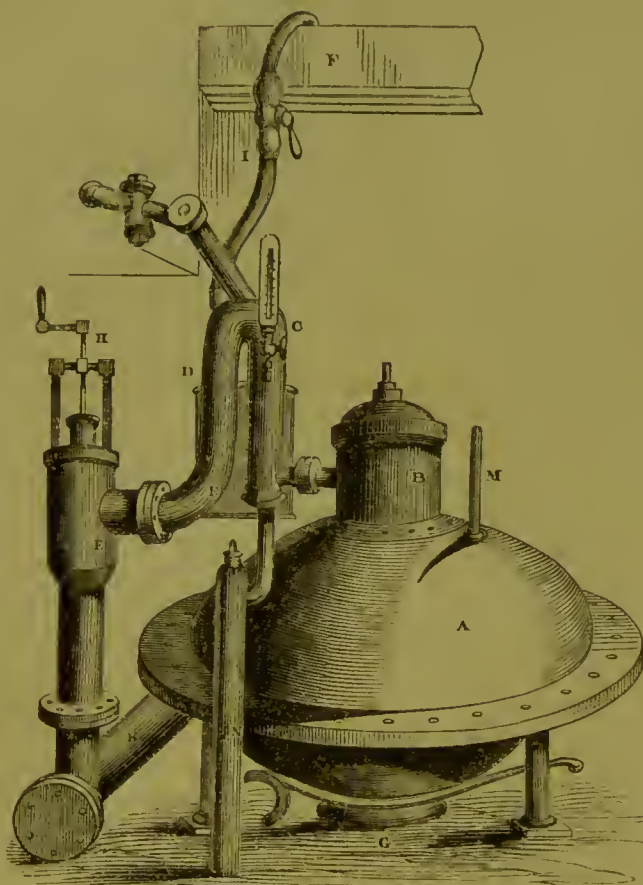
The following table gives the boiling point of the sugar in a vacuum pan, at different pressures of the air:—

Height of barometer in inches	Boiling point.		
	Fahrenheit.	Centigrado.	Reaumur.
0·74	115	46·11	36·89
0·86	120	48·89	39·11
1·01	125	51·67	41·35
1·17	130	54·44	43·56
1·36	135	57·22	45·78
1·57	140	60·00	48·00
1·80	145	62·78	50·22
2·05	150	65·55	52·44
2·36	155	68·33	54·67
2·72	160	71·11	56·88
3·10	165	73·89	59·11
3·52	170	76·67	61·33
4·00	175	79·44	63·56

The drawing on next page—Fig. 559—shows the various parts of HOWARD'S pan.

The principles employed in evaporating by HOWARD'S method, namely, the use of steam as heating

Fig. 559.



agent, and the employment of a vacuum, have received several modifications. These are principally those of ROTH, DEROSNE and DEGRANDE, and RILLIEUX.

The modification of ROTH consists in the absence of the air-pump to produce the vacuum. The vacuum is formed by condensation alone, and this condensation is effected in a separate vessel. It has not been found possible to work so entirely free from air. This process cannot be used without some aid from a pump.

The evaporating pans of M. DEROSNE differ from those of ROTH in the shape of the condensing vessel, which in the former's consists of a tube bent like a cracker, the folds of which lie in a vertical plane. Instead of effecting the condensation by water, DEROSNE employs sirup, which, being allowed to flow upon the upper fold of the tubes, trickles down from one fold to another. In condensing the steam in the inside of the tube, the sirup which flows down the outside of the tubes becomes itself heated, and parts with a portion of its water; while the heat of the tube and its vertical position determine an ascending current of air, which removes the vapor of water as it is formed.

DEROSNE's plan has been modified by M. DEGRANDE by the introduction of an air-pump to complete the vacuum, and employing the vapor given off from the sirup in one pan to heat the steam-pipes in a second

one. It should be mentioned that in DEROSNE's apparatus the sirup is allowed to flow from the pan into a closed vessel, so as not to impair the vacuum. The disadvantages of the plan of DEROSNE and DEGRANDE consist in the complexity of the apparatus they require; in other respects an excellent sugar is obtained with great rapidity.

The system employed by RILLIEUX is the same in principle as that of DEGRANDE. The vacuum is formed by an air-pump worked by a steam engine, and a succession of evaporating pans are employed, the sirup of each pan being heated by the vapor from the sirup of the preceding pan, and furnishing itself the vapor for heating the succeeding sirup. Each pan, however, may be connected directly with the boiler. The steam-pipes in each pan do not form, as is usual, one single layer, but they are piled upon one another like the boiler pipes of a locomotive.

5.—*Crystallization.*—Each mould stands over a separate earthenware basin, or over a leaden trough, which conducts to a cistern. When the moulds are filled with the concentrated sirup—the bung being in its place—the sirup after six or eight hours shows signs of crystallization. It should then be repeatedly stirred, so as to equalize the temperature throughout, and to distribute the crystals already formed, from which the subsequent crystallization is carried on. Several patents have been taken out for the purpose of using atmospheric pressure. The small ends of the sugar loaves may be united together, or, in other words, all may meet in a tube which runs along and connects itself with the pump. In

this way they are all readily drained. The loaves are then removed to a warm room of uniform temperature. After twenty-four hours' standing the loaf is set, that is, it has attained a sufficient consistence to admit of draining. It is with concentrated saccharine liquids as with all other saturated saline solutions, namely, that such a solution, during the process of crystallization, deposits crystals which are larger according as the crystallization takes place more slowly. Hence, if the sugar be required in large grains, the sirup should be kept still; if a fine-grained sugar be required, repeated agitation must be employed during the process of solidification. When the loaves are judged to be sufficiently set the bungs are withdrawn from below, and the mother liquid, which is of course a saturated sirup at the temperature employed in crystallization, is allowed to drain off for two or three days. It is a well-known fact that when a solid body separates in the crystalline form from a solution which contains foreign soluble impurities, the crystals are more free from such impurities than the liquid from which they separate. Hence, in the above-formed leaves, the crystals of the loaf are purer than the sirup which runs from them; they would indeed be of the maximum degree of purity were it not for the sirup with which they are still moistened. The next process consists in the removal of this adhering sirup. Formerly this was effected by the method of *claying*.

This consisted in scooping a shallow hollow in the thick and upper end of the loaf by means of an instrument called a bottoming trowel, and filling the hollow with a paste made of fine white clay and water. The water gradually leaves the clay and percolates downwards through the loaf, carrying with it the colored sirup, and dissolving also from the first strata a portion of the crystallized sugar. In its descent, as it becomes saturated with sugar, it acts simply by displacement, forcing out the colored mother-liquor or molasses from below. The fact that in this process a portion of the solid and whiter sugar is dissolved renders this method a wasteful one; it is now but little employed. In the process of *liquoring* the principle of displacement is alone employed. In this method the top of the loaf is levelled, and upon it is poured a saturated or strong solution of colorless sirup; as this sinks down it displaces the colored molasses. When the sirup commences to flow nearly colorless from the hole below, the loaf is allowed to drain, then inverted to distribute the sirup uniformly, and transferred to the drying oven. M. PAYEN mentions the following points in connection with the process of liquoring:—

1. The liquor must be sufficiently charged with crystallizable sugar to dissolve little or nothing in filtering.

2. The density of the liquor must be nearly the same or very little less than that of the displaced sirup; for if too dense it would flow badly: if too dilute it would escape without removing the sirup or molasses adhering to the crystals. To attain this condition the sugars used for preparing the liquor must be more impure in proportion as those to be liquored are so; for saturated sirups are more dense and viscid when they contain non-crystallizable sugar.

3. The crystallization in the moulds must be regular and not too compact; and for this end it must commence and terminate in the same vessel.

4. The temperature of the room in which the liquoring is performed should not vary much, and should be at least 70°. The operation of liquoring is performed as follows:—The crystallization is complete in twenty hours. The superficial crystalline crust is then removed from the base of each loaf with a trowel, and the surface is levelled. These surface scrapings—or rather those of a previous day's work—are added to sirup until the density becomes 67° Twaddell at 60°.

About five pounds of this liquor is poured at one time into each drained mould, containing about sixty pounds of crystallized sugar, which corresponds to ninety-three or one hundred pounds of concentrated sirup, put into the mould. This operation is repeated three times at intervals of twelve hours, and the sugar is then allowed to drain for three or four days. At the end of this time it may be put into casks, and it will be much drier and less alterable than ordinary brown sugar.

Instead of allowing the mother-sirup to drain out by the force of gravity alone, recourse is sometimes had to the pressure of the atmosphere. This is applied in the following manner:—The moulds are rectangular boxes, about six feet long, four feet broad, and two deep; they are called *tigers*. They are provided with false

bottoms formed of wire gauze or perforated plate. When the sugar is set the space between the real and false bottom is exhausted, and the pressure of the atmosphere forces the sirup from among the crystals of sugar into the hollow space. The mass of sugar which has been thus rapidly drained is either dried at once or previously stamped, to give it compactness, into brass moulds. It has been supposed in the above account, that loaf sugar is to be made; if so the filtered part is reboiled and again crystallized, by which means a sugar of an inferior color is obtained. The filtered portion of this second crystallization is also boiled down and crystallized, producing a third quality of sugar. The liquor from this last is the *treacle* of this country, or if clarified, it is the *golden sirup*. By this means the sugar is divided into *fine*, *seconds*, *bastards*, and *treacle*. Lump sugar is not necessarily white, nor is moist sugar necessarily brown. In making any of these sugars, the crystals are not allowed to stand and harden, unless lump sugar be wanted. If lump sugar be not wanted, the rotary machine is used instead of drainage to separate the sirup. At the same time, in the rough management of the colonies, one boiling down is common, the molasses coming from it being used for rum, or perhaps entirely thrown away, as frequently happens in Cuba, far from the coast.

The sugar with the adhering sirup is then introduced into the centrifugal drying machine, which is shown in Fig. 560 succeeding page.

The crude sugar is placed in the cavity as far as the rim extends. On bringing the drum into gear the box is turned round with a velocity of about 1000 to 1700 revolutions per minute. It follows that the contents of the box are forcibly pressed outwards. The crystalline grains are retained by the copper casing, while the molasses is forced through its interstices and thrown off into the outer reservoir. A rotation of a few minutes is sufficient for the drying of a charge of sugar. The machine is then stopped and the sugar is scraped out with a trowel. The sugar so obtained has seldom the brilliant whiteness of loaf sugar, nor does it possess the same compact form; but the immense saving of time effected by the use of the centrifugal drying machine is bringing it more and more into use.

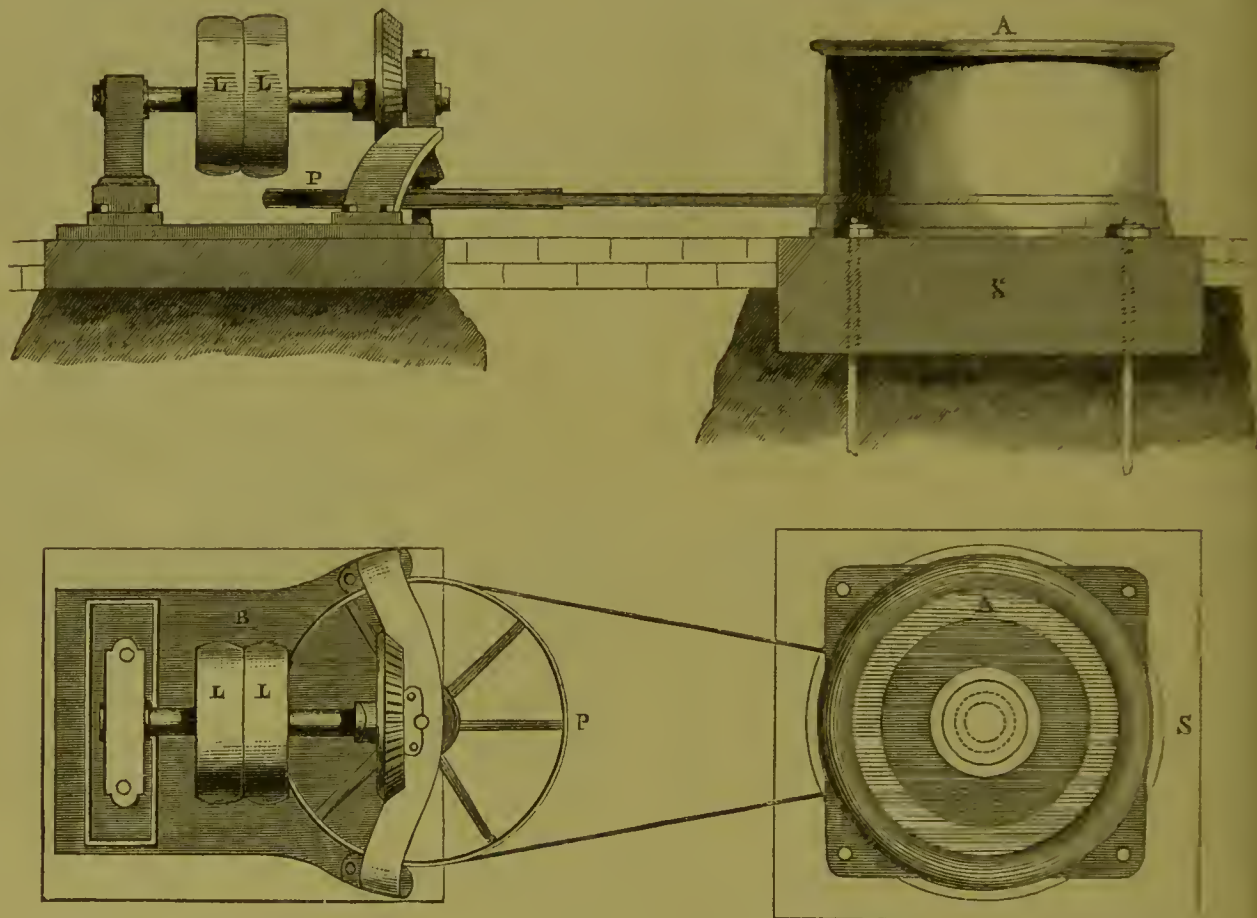
The very large crystals, remarkably distinct and difficult to dissolve, which have of late been manufactured, are made by boiling to partial crystallization in the vacuum pan; drawing off half and adding fresh sirup, this may be repeated to any size of crystals. In countries where the cane is grown, it is usual, to employ the molasses or treacle for the manufacture of rum, or to export it to Europe to the sugar refiners. The coarser kinds of sugar, moreover, which are made from unclarified or imperfectly clarified juice, and which are known as moist or brown sugar, are also bought by the European refiners, who separate the white sugar from the molasses which they contain. A great loss is experienced by the transportation of sugars from the Americas to Europe. This is in part occasioned by the gradual and more complete separation of the molasses which drains off and escapes into the hold of the vessel, such draining being greatly facilitated by the motions of the vessel; but partly and perhaps

chiefly by the escape of the sugar which such motions produce. The whole bulk of a sugar vessel becomes impregnated with sugar, and metallic bodies in the ship which are far removed from the sugar in cargo, become speedily tarnished and corroded, owing

to the deposition upon them of particles of sugar, and the subsequent fermentation and acidification of such sugar.

Sugar Refining.—The great difference in price between coarse and white sugar, the cheapness of fine

Fig. 560.



and the facilities of making and repairing machinery in Europe, have given birth to its sugar refineries. In the sketch of the preparation of sugar from the cane—Fig. 560—it is supposed that the whole process is carried through at once. But where the crude products from the colonies are bought by the European refiner for purification, his process differs only from the above-described one, inasmuch as he has at starting solid brown sugar or molasses to deal with, instead of the juice of the cane at its natural degree of dilution. The refiner, therefore, at starting has to dissolve his sugar or dilute his molasses to the necessary degree in order to submit it to filtration. The processes which the refiner has to perform depend, of course, entirely upon the nature of the raw sugar with which he has to deal. In most cases the material which comes into his hands has undergone the process of defecation, but not that of filtration, or the filtration where performed has been very incomplete. To dissolve the raw sugar warm dilute sirup is employed. The sugar is agitated with the sirup by means of a flanged wheel worked by machinery, and the product is then pumped up to the top of the refinery. It then undergoes the various processes of filtration through cotton bags and charcoal and evaporation, which have been already described. In refineries the evaporation is always effected in

vacuum pans, and the drying is generally performed by the centrifugal machine.

Abridged description of the Process of Refining.—As conducted in sugar works here, the process of refining consists simply of the following operations:—The bags are cut up and thrown aside to have the sugar washed out of them. They may be thrown away, or they may be sold for paper, according to their value. The sugar is thrown into a pan which will contain from two to three tons of it in solution. Sometimes it is broken up by a spade, sometimes by machinery cutting it with revolving knives. It is heated more or less; some bring it to boiling. Frequently, if not generally, it is treated with a little lime water; this is called defecation, or blowing up. It is then sent through the bag filters, from which it passes into great iron tanks, where it waits till a charcoal filter is ready. It then passes on to the charcoal filter, and from thence to the vacuum pan to be boiled down. It is then set to crystallize. When this is done, it is freed from its liquid sirup or molasses by the centrifugal machine. Instead of being put into this machine, it may be poured into sugar loaf moulds and washed with sirup. This is sometimes called claying, and is made to sound mysterious. Both processes are one in principle, as sugars when put into the centrifugal machine are in reality washed with sirup.

	Beaume.	Fahr.
Defecation takes place at.....	27 and about	180°
Syrup runs from the charcoal at	27 "	80°
Syrup from first crystals.....	40 "	100°
Reduced to 25° Beaumé for boiling to obtain second crystals—		
Drainage from second grain....	40 "	100°
Drainage from third grain	34 "	80°
Drainage or treacle at the last	41-43	

Sugar is soluble in one-fifth of its weight of boiling water, and one half its weight of cold water. Six pounds of sirup, containing five of sugar and one of water, deposit on cooling three pounds of sugar, leaving three pounds of sirup containing two of sugar. Sirup containing one of water to five of sugar boils at 238° Fahr., but it is evaporated till the boiling point is as high as 240° or 242°. If evaporation takes place in the open air, this temperature is actually attained; if HOWARD'S pan is used, no matter what variety of shape be chosen for the pan, the vacuum brings down the boiling point as low as to 145°, but on an average we may say that the sugar is boiled down in the vacuum pan at 160° Fahr. In the open air the appearance indicates the condition of the sirups. In this country the vacuum being of necessity used, a specimen of the sugar is removed by the proof stick. This is simply a brass rod, which is driven from the upper part of the side of the vacuum pan down an aperture made of the same size as the rod. When it reaches the bottom, the rod is twisted half round by the cross handle, and opens a communication with the end of the rod and the sirup. In the end of the rod is a groove into which the sugar enters; the rod is half turned again and drawn out, and the entrance is closed as at first. A portion of sugar is taken between the finger and thumb, and the indications are obtained which have been already described. When the sugar is ready, the vacuum pan is opened, and the sugar falls out into a large copper. There are various ways of disposing of it at this period; but in every case it is put into a series of small vessels. If loaf sugar is to be made, it is here heated up to nearly boiling. In some places it is put into pans of earthenware not unlike, or it may be exactly like the sugar loaves, even although there is no intention of making loaf sugar. Sometimes these vessels are made of zinc, and painted; iron has been tried. Sometimes the vessels are very large, containing from one to ten hundredweight of sugar. These vessels are allowed to cool slowly. For fine sugar 90° Fahr. is used, for common 115° Fahr., during which time the crystallization takes place. Every vessel must, of course, have an aperture at the bottom, which is opened for drainage as soon as crystallization has commenced. Each vessel has a drain under it communicating with a general receiver; when the drainage ceases the sugar—in houses on the newest system—is taken to the centrifugal machine, unless, of course, loaf sugar be made. The time of standing is from two to six days. The sugar when crystallized is surrounded with colored sirup, not so pure as the sirup which comes from the charcoal; time and workmanship have produced a dark hue again. It has become exceedingly hard, the crystals being strongly held together, some very dark-colored sirup still remaining. It is removed from the moulds or forms by a pickaxe and spade, or

more frequently by a cutter, which is of the same curve as the inside of the crystallizing vessel, and which, being driven by considerable force, scoops out the sugar readily. In order to remove the liquid about three minutes are required. It is often the case that the sirup has hardened too much, and it is then needful to soften it with a jet of steam, which enters the side of the *hydro*, as the hydro-extractor is technically called. The liquid, with all the impurities, flows off by an underground pipe, and is used again. The first crystallization produces fine sugar; the next, seconds; and the third, bastards. The uncrystallizable treacle is the fourth product. When loaf sugar is to be made, the moulds are of the well-known size, containing about thirty pounds.

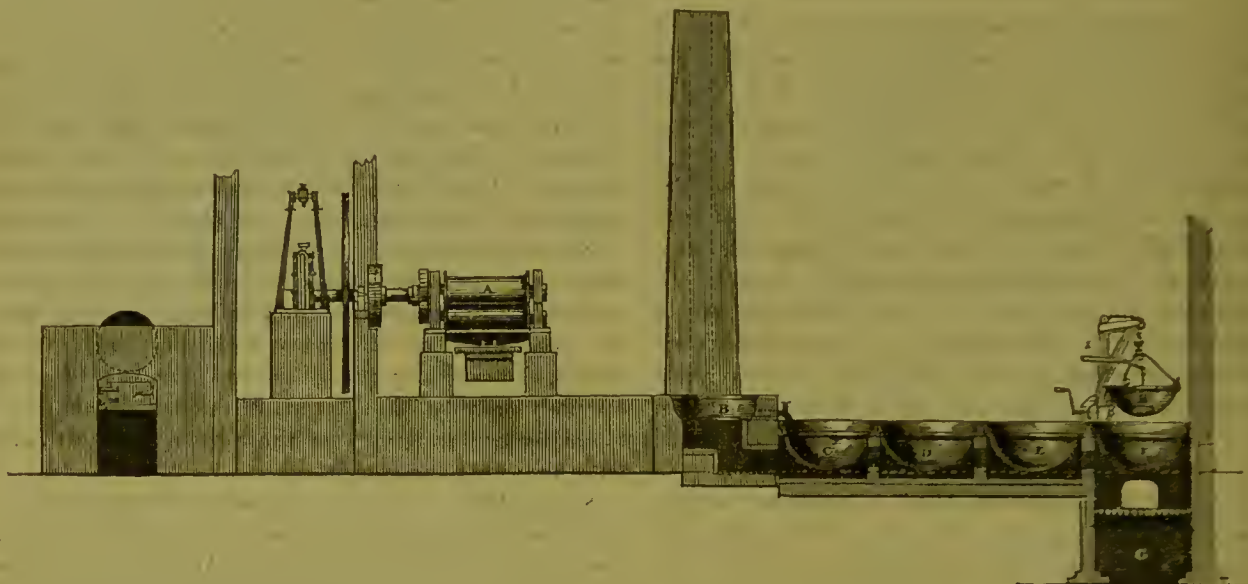
Special description of the more complex machines, with some additional details.—In order not to load the account of the processes used in sugar refining with the description of too many machines and minute details, the special parts of the apparatus will be more minutely described in this part of the article, and additional particulars given for those who desire to enter more fully into the subject.

Sugar Mill.—Fig. 561 represents the arrangement of mill and boiling-house as used in the colonies. The size of a sugar plantation in the West Indies varies from one hundred and fifty to two thousand acres, producing from one hundred to five thousand hogsheads of sugar per annum. The boiling-house should be situated in a central position on the plantation, to avoid loss of time in carriage of the canes from the fields to the mill. The mill A—Fig. 561 and drawn to a larger scale in Fig. 554—consists of three heavy cast-iron rollers, about two feet four inches diameter and four feet long, fixed in strong cast-iron frames. The canes are fed from the feeding table, B—Fig. 554—and are squeezed twice between the top roller, C, and each of the two lower rollers, D and E. The megass, or solid part of the cane, after being squeezed passes from the mill by the shoot, F. A trash-turner, G, is placed between the two lower rollers, and under the top one, to guide the canes between the upper and second lower roller. The spaces between the upper and lower rollers are adjusted by the screws, H H; the space between the top and first lower roller should be a quarter of an inch, the second lower roller being set close to the top one. The juice drops into a trough below, from which it runs to the clarifiers, directly if possible; but if the mill cannot be placed sufficiently high to command the clarifiers, a pump is used, worked from the top roller spindle and fixed in a cistern under the trough. The speed found most advantageous for expressing the juice from the canes is at the rate of twenty feet per minute at the periphery of the rollers. The two lower rollers are driven from the upper one by spur pinions, I I I, keyed on the ends of the spindles. The mills are driven by steam—as shown in the drawing—but sometimes water or wind power is used according to the physical character of the country in which it is used. Cattle are also employed to work them in some places, especially on small estates where fuel is difficult to be obtained. In cattle mills the rollers are usually vertical instead of horizontal, being simply driven by yoke arms fixed to the spindle of the

centre roller; the cattle working from the ends of the arms. The rollers, three in number, are fixed in a line with each other, the two outside ones being driven from the centre roller by spur pinions keyed on the tops of

the spindles. The weight of the rollers is carried on hardened steel plates fixed in the framework of the mill; a steel toe being fitted to the bottom of the spindle to bear on the steel plates. The canes are fed

Fig. 561.



between the first and centre rollers, the megass coming out on the same side between the centre and third roller, a piece of plate-iron bent to a sweep corresponding to the diameter of the centre roller, guiding the canes round to be squeezed the second time between the centre and third rollers. The juice falls into a trough placed under the three rollers. A cane carrier is often used to supply the canes to the horizontal mill. It consists of two endless pitch chains working over barrels, the upper one being driven from the spindle of the top roller by spur-wheels or another endless pitch chain. On the outer side of the chains are attached boards sliding over a wood framing, with a ledge on each side to keep the canes on the carrier. The top of the carrier is level with the top of the feeding table and extends some thirty feet from the mill. The canes are delivered on the carrier instead of on the feeding table of the mill, which facilitates the work, besides causing the mill to be more regularly supplied with canes than when they are delivered on the feeding table of the mill.

Clarifiers.—The juice, as it is expressed from the canes, runs into the clarifiers, one of which is shown at B—Fig. 561. Two are generally used, one filling while the juice in the other is clarifying. They are generally cylindrical copper-pans with crown or arched bottoms to resist the action of the fire. They are fitted with a large cock at the bottom for running the juice into the first copper. They are set in brickwork at the end of the battery, the flame passing under them previous to going into the chimney, a damper being provided to each to direct the flame under the one that is full. Milk of lime is added sufficient to neutralize the acid in the juice.

The battery is a range of pans, C D E F, with the fur-

nace, G, at one end. The fire passes under the range, and under either of the clarifiers to the chimney. The pans are hemispherical in shape, diminishing in size from the first copper, C, under the clarifiers, to the striking teach, F, in which the evaporation is completed. As the juice becomes concentrated in the pans nearer the furnace, they are filled up from those behind them, until the striking teach is sufficiently full, and the sugar in it concentrated to the granulating point. It is then ladled into shallow wooden vessels, where it is allowed to cool, and from thence it is conveyed into the hogsheads in the curing-house. An improvement in the old system of ladling from the striking teach to the coolers is now much used. It consists of a copper pan, H, fitting the inside of the striking teach as accurately as possible. At the bottom of this pan or dipper is a large valve opening towards the inside of the dipper, the valve being worked by a lever, I, over the side, and a chain from the ground. The dipper is attached to a crane, J, which commands the striking teach and a gutter to the coolers. The advantage of the dipper is that the striking teach can be emptied and refilled in much less time than by the ladle, and consequently there is not so much risk of burning the copper and the sugar. A gutter is made in the brickwork at the side of the battery into which the impurities that rise to the surface of the liquor are skimmed. The skimmings—from which are distilled the best rum—are conveyed from the gutter to a tank previous to fermentation. The floor of the curing-house, in which the molasses is drained from the sugar, is composed of a series of gutters which incline to the centre of the building and deliver their contents to a main gutter which communicates with a tank for the molasses. The hogsheads are placed on end over the gutters.

small holes being bored in their ends for the passage of the molasses. The sugar, after remaining in the curing-house about fourteen days, is ready for shipment, and is known in the market as raw or muscovado sugar.

The megass, after passing through the rollers of the mill, is dried and used as fuel for the battery; being better suited for that purpose than any other convenient fuel, as far as heat goes, a very quick fire being required. A saving of fuel is effected by placing the boiler of the cane-mill engine at the end of the battery, so that the products of combustion may pass from the battery through the boiler flues, previous to going into the chimney. A furnace is fitted to the boiler for use before the battery is at work in the morning, and which can be shut off when not required, the waste heat from the battery being almost sufficient to work the boiler for the cane-mill engine.

In the striking teach of the ordinary battery there is a liability of the upper part of the teach becoming overheated, and so making the sugar of a darker color when it splashes up against it, depreciating its value. A pan made so that the heating surface is entirely covered with liquor is used in some places, called a *bascule* or *tiltpau*. It is a shallow, cylindrical, copper pan, about five feet diameter and two feet deep. It is furnished with a lip to run off the sugar, and works on a hinge under the lip. The pan is set over a fire, and when the sugar is boiled to the granulating point, it is tilted up by a lever and chain fixed to it. The sugar being turned out at once into the cooler, there is not the same risk of burning as in the ordinary fixed pans.

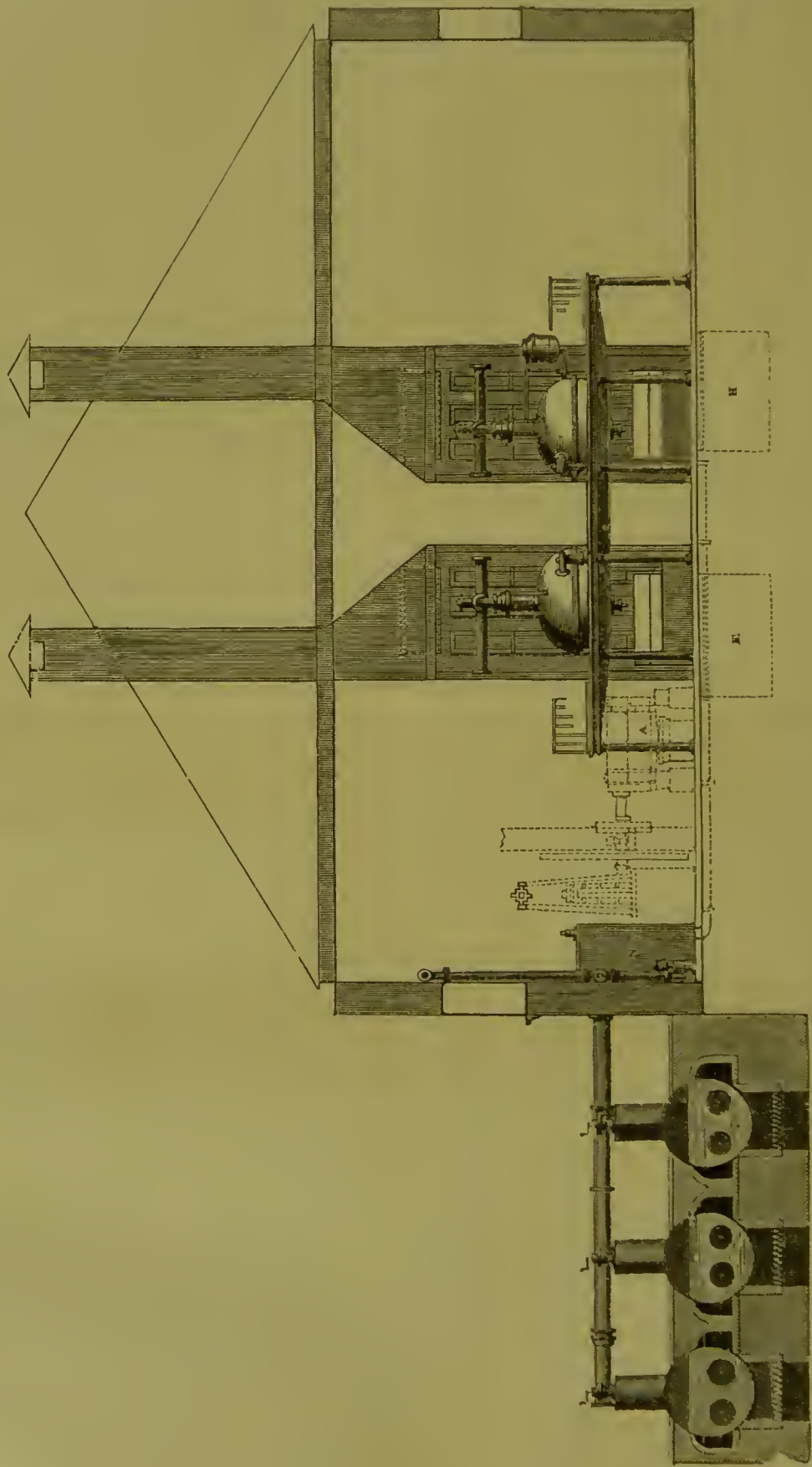
Rectangular copper pans with crowned bottoms have also been substituted for the hemispherical pans with cocks or valves, to empty them from the bottom. They are ranged side by side over the furnace, so that the flame runs under them from end to end; and there being no side flues, the metal of the pans does not become heated, and consequently the quality of the sugar is not injured.

Figs. 562, 563, 564 show a boiling house fitted up with the latest improvements in the machinery connected with the manufacture, for facilitating the process and improving the color and quality of the grain. It is worked wholly by steam heat, as being more economical in the working, and admitting of more perfect regulation of temperature. The juice from the mill, A—as described before—is forced up to the top of the building to the clarifiers by a *monte-jus* or juice elevator, B, consisting of a wrought-iron vessel into which the juice flows from the mill by a pipe and cock. Another pipe is fixed to the top of the monte-jus and rises to the required height, dipping down to near the bottom of the monte-jus; the steam being admitted at the top forces the juice up the pipe. This is more convenient than a pump, is cleaner, and not so liable to acidify the juice. The clarifiers, C C C, used here are hemispherical copper pans, hammered out of one piece of copper fixed by a flange laid off to an outer cast-iron pan, allowing a space between the pans for steam. A copper light course is fixed to the top, the heating surface not being required up to the top of the pan. A valve is attached at the side to regulate the supply of steam, and a two-way cock at the bottom;

the smaller branch being for the clarified juice, and the larger for the scum. The juice in the clarifier is raised to a temperature of 176°. Milk of lime is added sufficient to neutralize the acid in the juice. The heat is then continued till a scum, consisting of impurities present in the juice, has risen to the surface and appears about to crack. The time occupied in this should be about ten to twelve minutes from the commencement of the operation. The steam is then shut off and the liquor allowed to subside for fifteen or twenty minutes, when the scum will be found to remain at the top; some heavy matter, such as dirt, *et cetera*, will have fallen to the bottom, and between them will be the clarified cane juice, clear, and of a pale straw color. The clear liquor is separated from the impurities in the following manner:—At the bottom of each clarifier is a plug, ground into the top of the cock, with a rod and handle above the top of the clarifier. At the side of the plug are holes about three or four inches above the bottom of the clarifier, adjustable by a copper clip, below which all the heavy matter will have accumulated. The clarification then being complete, the cock is first turned on to the smaller aperture until the scum accumulated at the top begins to appear. The cock is then turned to the large way and the plug taken out. The heavy matter at the bottom and the scum formed during the process are conveyed to a cistern, from whence it is placed in bags, and any juice remaining in it is squeezed out, leaving only a small portion of solid matter behind. The clarified juice or liquor, after coming from the clarifiers, is passed through mechanical filters. The kind commonly used are rectangular cases of cast or wrought iron with an internal flanch at the top to support a copper box, about twenty inches deep, to receive the liquor to be filtered. At the bottom of the box a number of holes are drilled and screwed to receive the bells or connections, to which filter bags are attached. These bags are made of twilled cotton cloth, about six feet in circumference and six long, wove without a seam. They are inclosed in a strong open webbing, about eighteen inches in circumference, thus giving a large surface of filtering medium in a small space. The filters are shown at D D D. The liquor is drawn off at the bottom into a receiving cistern, E, to supply the evaporating pan. Steam cocks are attached to the side of the cases for cleansing them after use; and doors are fixed to them for changing the bags. The evaporation is here effected in *vacuo*, as being most advantageous, the liquor boiling at so low a temperature as not at all to discolor the liquor or alter the saccharine matter in it. The first cost, however, of the apparatus is increased, and alone prevents its universal adoption.

The vacuum pan, F, used for the evaporation of the liquor, consists of a copper pan fitted in a cast-iron steam case, allowing a space between for the steam, and on the top is a copper dome; the copper and iron pans and dome being accurately fitted and bolted together, so as to be perfectly steam and air tight. In order still further to increase the heating surface, a large brazed copper worm is fixed inside the pan. A manhole, with a ground brass cover, is attached to the top of the dome, from the side of which a pipe leads to the receiver or safety vessel, furnished with a glass

Fig 562.

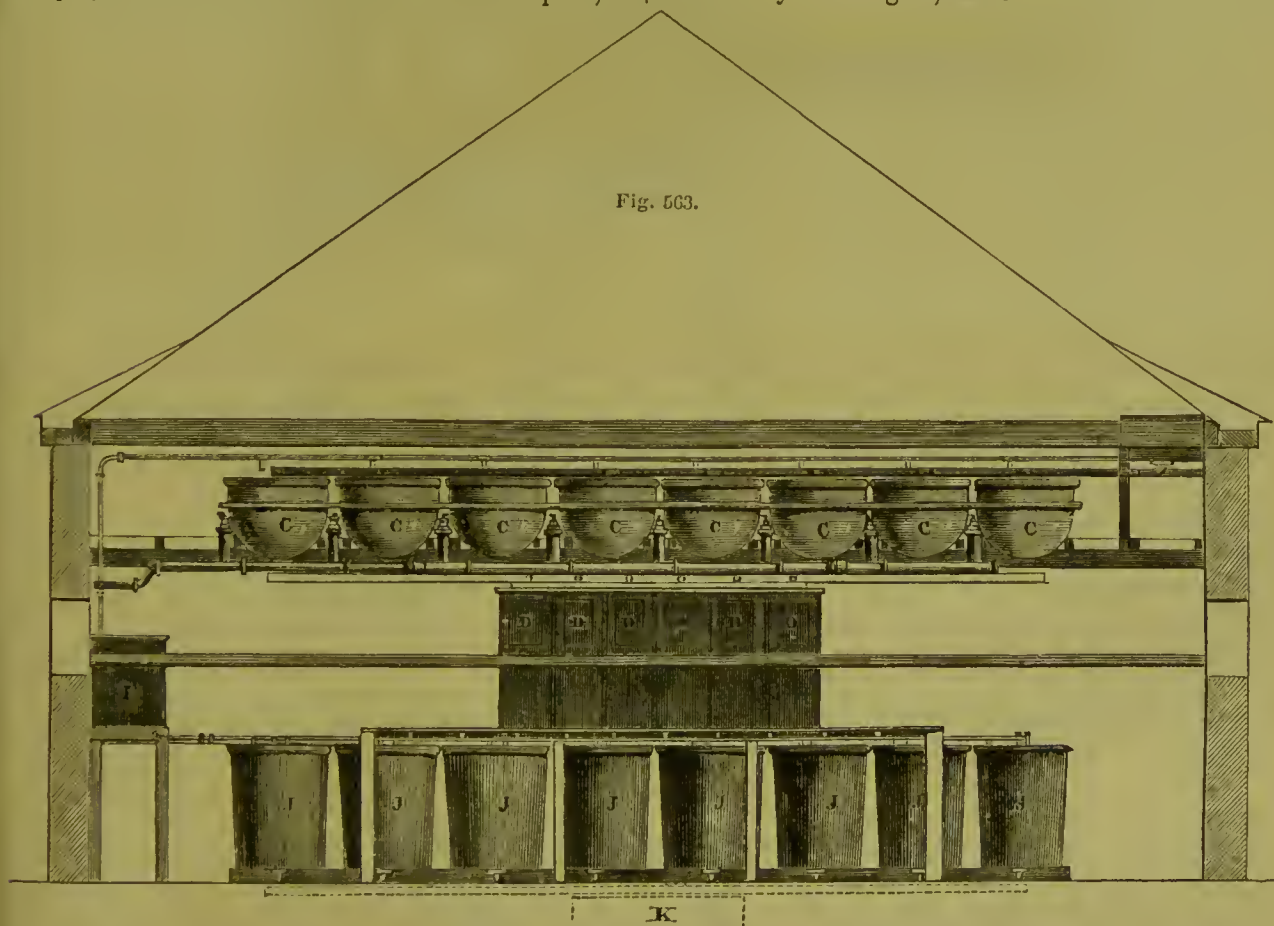


guage and draw-off cock, the use of which is that the attendant may see if the pan primes or boils over; if it does, the sugar must fall into the receiver, and be indicated by the guage. A pipe from the top of the receiver, with a valve to shut off the communication, connects the pan with the condensers. The pan is fitted with a cock at the bottom for running off the liquor when sufficiently concentrated, namely, at about 36° Twaddell. On the dome of the pan are fixed a barometer; a thermometer, with bulb dipping down into the liquor; light and sight glasses for looking into the pan; an apparatus for testing the concentration of the liquor without destroying the vacuum in the pan; air-cock for letting in the air when the liquor is required to be drawn off; and a steaming valve for cleaning the pan after work. Surface condensation is employed to maintain a vacuum in these pans, in

situations where there is not sufficient water to admit of condensation by injection being used.

The surface condensers are here shown, G G G. This process of condensation was introduced and patented by Messrs. PONTIFEX and WOOD of London, who have recently patented a simple and efficient method of connecting the pipes—admirably adapted for the colonies, and all places where skilled labor is difficult to be obtained. The condensers consist of one or more series of copper pipes, fixed to boxes at each end, with partitions to direct the current of the vapor. Above each series of pipes is fixed a trough always kept full of water, and so constructed that the water trickles in a gentle shower, uniformly spread over the pipes, so as to keep them well covered with a thin film of water; the lowest pipe is connected with a small pump, worked by the engine, which draws the condensed

Fig. 563.

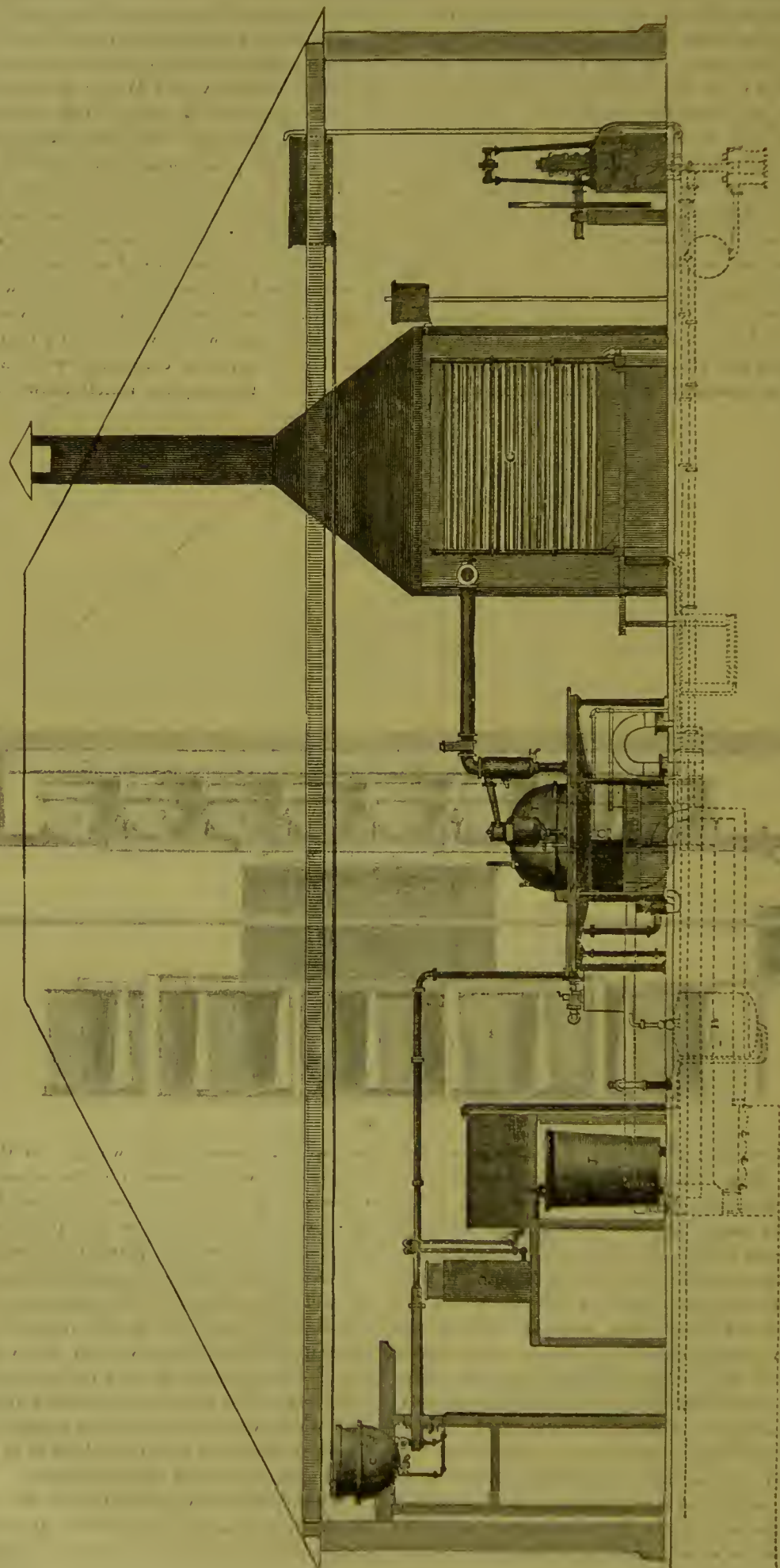


vapor from the pan, and any air that may have collected there. The improvement referred to consists in doing away with solder joints at the junction of the pipes with the case, the solder being liable to crack from the unequal expansion of the pipes, owing to the lower pipes being cooler than the upper ones, and the substitution of an elastic joint, which allows for the irregularity of the expansions, without injuring the vacuum; they are also easily replaced, not requiring any mechanical skill, and take up less space for shipment; these pipes and cases being packed separately. The superior economy of water in these condensers, is owing to the condensing water being evaporated and carrying away not merely sensible but latent heat. The ordinary method of condensation is similar to that employed in the condensers of steam engines, when the steam is led into a vessel, where it is brought into con-

tact with a stream of cold water. In this case, as the condensing water must be allowed to become vaporized, all the heat it absorbs must be in the form of sensible heat, and it is said practically to require about thirty times the quantity of condensing water; but in these surface condensers the vapor which passes off from the surface of the pipes, not only carries off the sensible heat, but it also renders latent a great amount of heat in its conversion into vapor, the quantity of water passing off from the surface being equal or nearly so to the quantity condensed inside the pipes. The water which falls into the trough under the condenser is used over again, the heat of it not materially affecting the action of the condensers.

When sufficiently concentrated, the sugar-liquor is let down into a receiving cistern, H, placed below the pan, from whence it is forced up by the monte-jus to

Fig. 564.



a cistern, I, above the level of the top of the charcoal filters. The charcoal filters, J J J J, are large, slightly conical vessels, generally of wrought-iron, with a perforated false bottom about an inch and a half from the bottom. A blanket is spread over the false bottom to prevent the charcoal from being carried through with the liquor; some, however, always accompanies the liquor at first, which runs into a separate receiver to be filtered over again. In filling these vessels, the first few inches of charcoal should be pressed compactly down, after which it is packed lightly but evenly, nearly to the top, where space is left to receive the liquor. The object to be attained in these filters, is to remove all the vegetal coloring matter from the liquor, and any excess of lime that may have been added during the clarification, as well as some of the mineral salts, such as sulphate of lime, originally existing in the cane juice. The liquor from the charcoal filters runs into a cistern, K, preparatory to being drawn into the granulating pan.

The granulating is also performed in vacuo, and the pan, L, is similar in its construction to the one before described for evaporation, and a similar surface condenser is applied when there is a deficiency of water. To the granulating vacuum pan a measure is usually attached, so that the attendant may know exactly how much liquor he lets into the pan. There is also a proof stick or instrument for taking a sample of the sugar out of the pan during the concentration, without destroying the vacuum. A slide is fitted to the bottom, instead of a cock, for letting out the sugar when the granulation is completed. The pan is also fitted with light and sight glasses, barometer, thermometer, *et cetera*.

The sugar, on being let out of the pan, drops into a heater, M, a hemispherical pan of a similar description to the clarifiers described before, in order to raise the temperature of the sugar above what it was in the pan, to harden the grain previous to being conveyed to the curing-house. The water arising from the condensation of the steam in the various vessels, passes from the bottom through a condense water box attached to each vessel, in the interior of which box a float and valve are so arranged that the water passes through without letting the steam escape. The outlet pipes from the condense water boxes are carried to a cistern, into which the suction pipe of the feed pump to the steam boilers dips, to be used over again to supply them, a very small quantity of cold water requiring to be added to make up for loss by waste. In some parts of the manufacture, high pressure steam being required, such as for clarification, for the steam engine, and the montejus, it is found better to keep the steam up in the boilers to a uniform pressure, lowering the pressure to the vacuum pans and heaters when the temperature of high pressure steam would injure the quality of the sugar. N represents an expansion vessel for effecting this purpose, and is fitted with one of Messrs. PONTIFEX and WOOD's patent improved valves, by which the steam in the expansion vessel is sustained uniformly at any required pressure. However high or fluctuating the pressure may be in the boilers, the excess of pressure shutting the supply valve to the expansion vessel,

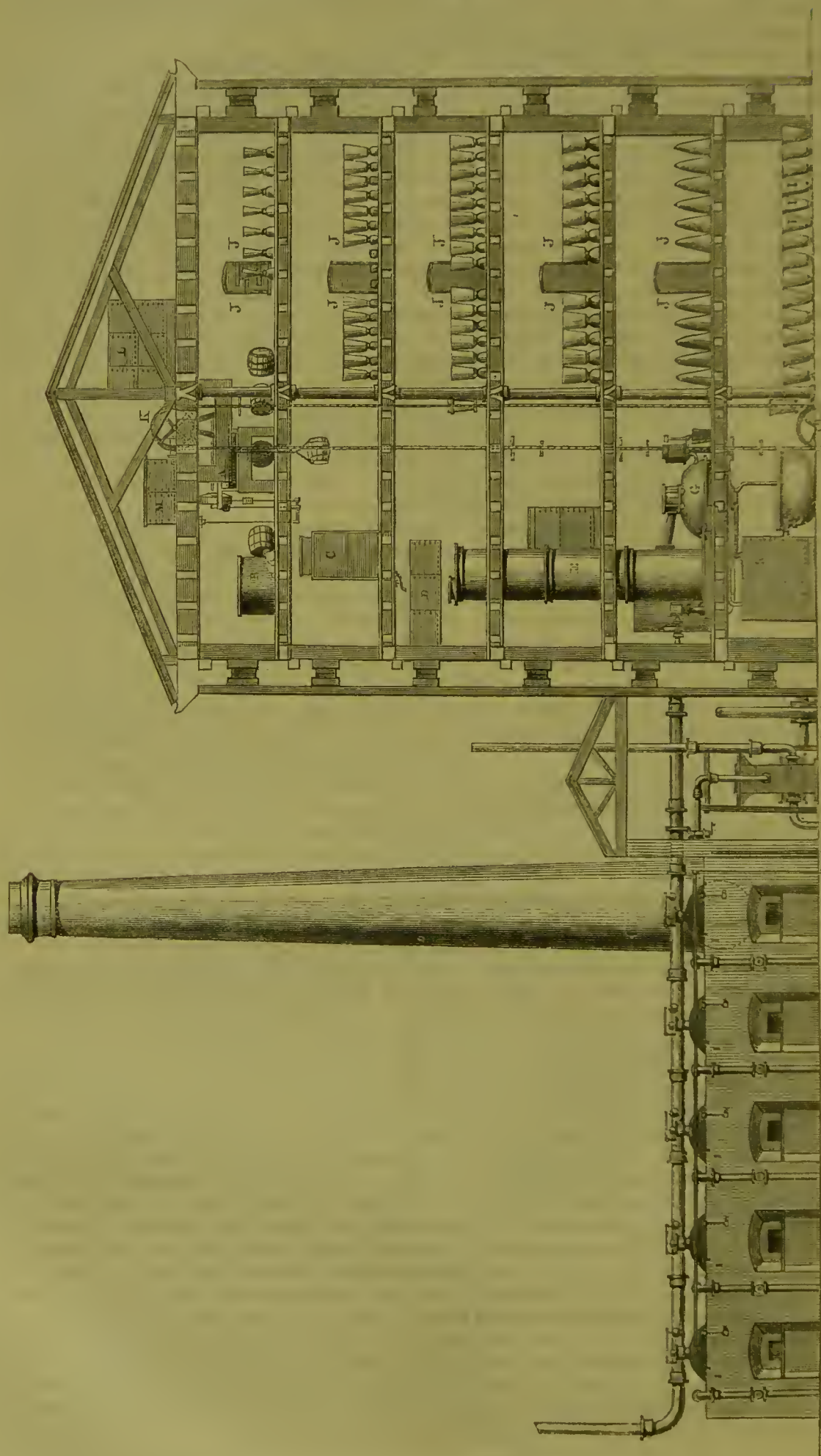
safety and whistle valves are attached to the top, and a gauge on the side to indicate the pressure of steam.

The evaporation of the juice, up to 48° Twaddell, may be carried on in the ordinary battery of hemispherical pans or the improved rectangular ones, as previously described, without being seriously detrimental to the liquor, although the plan last described of evaporating, as well as granulating in vacuo, is most approved. A better method of evaporating than by direct fire heat is by using steam evaporators—the best form of which having the largest heating surface, combined with facility for cleaning, is a rectangular vessel, generally of wrought-iron, at the bottom of which is placed a range of copper pipes as close to each other as convenient. The pipes are connected together by copper bends brazed to the pipes. The entrance of the steam and exit of the condensed water are at the same end of the evaporator, and pass through stuffing boxes, to admit of the pipes being turned up, so as to be able readily to approach all parts of the evaporator to clean them—a point of great importance in the manufacture.

Machinery and apparatus, such as those described in the preceding, and fitted with all the modern improvements are, it is true, costly in erection, but they very soon pay for themselves in the superior quality of the article produced, and the greater return from the same quantity of canes. By employing the strong mills and powerful engines as now manufactured, the canes yield a much larger per centage of juice than previously; and the megass leaving the mill being much dryer is in a better condition to be used as fuel. By applying steam heat, and boiling in vacuo at low temperatures, the color is improved, and less of the sugar is converted into molasses, so that estates which were worked at a loss before may, by the introduction of improved machinery and utensils, be made to yield a profitable return. In colonies where field labor is difficult to be procured, it is especially important to the planter to obtain the most approved machinery, so as to cause as little waste as possible of the raw material.

The machinery of a sugar refinery as worked in Europe is shown in Fig. 565, which represents the elevation of a refinery of the most modern construction, for the conversion of the raw sugar, as imported, to the white loaf sugar of the consumer. The raw sugar, in hogsheds, boxes, or bags, is lifted from the waggon to the upper story of the house by a crane worked by a steam hoist machine, A. The first operation is to melt the sugar, which is usually done in cylindrical or rectangular open pans, one of which is shown at B. At the bottom of the melting, or *blow-up* pans, as they are termed, is a perforated copper worm, and over the worm is a perforated false bottom to keep back any large substance that might be mixed with the sugar. After adding to the sugar a sufficient quantity of water to bring the density of the liquor, when dissolved, to about 44.5° to 46.5° Twaddell, the steam is then turned on, mixing directly with the sugar; whilst being dissolved, bullock's blood—still in some places—and lime water are added to clarify it and neutralize the acid. Mr. FINZELL

Fig. 165.



of Bristol, one of the largest sugar refiners in the world, has patented a modification of the vacuum pan in place of the ordinary melting pans, which he thinks expedites the operation of melting; the sudden expansion of the air confined among the sugar assisting the steam and water in the breaking up and melting of the mass. A movable false bottom is placed over the worm to allow a space for the water between the sugar and the heating surface, and to keep back any extraneous matter. Messrs. FINZELL and ASPINALL have also recently patented a new form of pan for melting sugar, in which the sugar is suspended near the surface of the water in such a way that, as it becomes dissolved, it falls by reason of the greater density of the solution to the bottom of the pan, leaving the next stratum to be acted on by water not so saturated with sugar; whereas, if the sugar lies at the bottom of the pan, the water in immediate contact becomes thoroughly saturated, and, remaining at the bottom by reason of its density, retards the dissolution. This is, however, compensated for by a large stirrer, universally used in blow-ups. On emptying the hogsheads, *et cetera*, a portion of sugar is left behind sticking in the crevices of the staves; this is removed by placing the hogshead in a steamer—when, the steam being turned on for a short time, all the sugar is washed out of the hogshead, and drops mixed with the condensed steam to the bottom, from whence it is conveyed to the melting pan.

From the melting pan, B, the liquor is drawn off to the bag filter, C, similar to those described before for the cane juice. The liquor then runs into the receiving cistern, D, with a coil of copper steam-pipe at the bottom to increase the temperature previous to entering the charcoal filters. The charcoal filters, one of which is shown at E, as generally used in refineries, are cylindrical vessels of cast-iron or copper, about five feet diameter, and twenty to thirty feet high; the greater the depth of charcoal the liquor has to pass through, the less coloring matter is left in the liquor. The filters are furnished with a perforated false bottom, a blanket being spread over it to prevent the charcoal from passing through with the liquor. The tops are generally closed, to admit of a head of liquor above the charcoal to accelerate its passage through the filter, a manhole being cast in the cover to let in the charcoal, and another at the bottom to get it out when required to be changed. From the filters the liquor runs into a cistern, F, placed on the basement or *fill-house* floor, from which it is drawn up into the granulating pan, G. A vacuum pan is used for this purpose similar to the one before described for granulating the sugar from cane juice; only in this drawing the condensation is shown, effected by the injection of cold water into a vessel when it meets the vapor from the pan: this method is adopted when water is abundant, the outlay not being so great. The sugar, when granulated, is let down into the heater, H, by a slide in the bottom of the granulating pan, the sugar requiring the temperature to be increased in order to harden the grain; it must also be well stirred, to mix the grain thoroughly previous to being ladled out into the moulds. This operation of ladling is usually performed in copper

filling-out basins, into which the sugar is ladled from the heater. When practicable, labor may be saved by raising the pan and heater up to a floor above, so as to draw the sugar off from the bottom of the heater by a slide.

CENTRIFUGAL MACHINES.—If the sugar is intended to be in the form of crystallized, from the heater it is put into the centrifugal machine, which consists of an outer cylindrical case, in which revolves at a very high speed an inner vessel perforated round the circumference, into which the sugar to be dried is placed; the centrifugal action from the velocity causes the sirup to pass through the perforated circumference into the outer case, from whence it is drawn off, leaving the crystallized sugar behind. By this means much time is saved in the draining of the sugar. The same effect is sometimes attained by connecting the bottoms of the moulds to a pipe communicating with an air-pump, when the pressure of the atmosphere acts in the same manner as the centrifugal force; or the sugar is placed in a large box fitted with a perforated false bottom, from which the air is exhausted. This latter plan is often adopted with much success in the West Indian Colonies.

The moulds, I, I, I—Fig. 565—into which the sugar passes from the heaters, are of a conical shape, and usually made of sheet-iron; the lower part or apex of the cone being of cast-iron, with a small hole for the sirup to drain through. They are either painted or galvanized inside and out, to preserve them from rust; they are made of different dimensions, according to the size of the loaves required and the quality of the sugar, and are named respectively—loaves, titlers, lumps, and bastards. From the fill-house the moulds are conveyed to the various floors, which are heated by steam-pipes to a temperature of 75° to 80° Fahr., to facilitate the drainage. The moulds are ranged all over the floors, with the points of the moulds resting on iron or earthenware pots, to receive the sirup drained from them. After standing some time till their own sirup drains from them, fine liquor, consisting of a saturated solution of pure sugar, is poured on the top of the moulds, thus, as it percolates down the loaves, washing away with it the impurities remaining on the sugar, which would otherwise adhere to the surface of the crystals. After this the loaves are taken out of the moulds, the lower end is cut to a point in a nosing machine, as it is called, and the top trimmed off by a machine with revolving knives. The ends so cut off are not of equal quality to the centre of the loaf, and are melted over again. The loaves are then papered up and further dried in a stove, J, which is heated by steam pipes at the bottom, and fitted with shelves on which the loaves are placed. After drying they are ready for the market. The moulds are lifted from one floor to another by a machine called a mould-hoist, which is driven by the engine. The mould-hoist, as made by Messrs. PONTIFEX and WOOD, is shown at K, K, and consists of two endless pitch-chains working over pulleys fixed under the fill-house floor, and at the top of the house; between these chains are slung cradles, with rings adapted to the various sizes of moulds used in the house. Holes are cut in the various floors

sufficient for the passage of the moulds, which are readily placed in and taken out of the cradles as they pass up or down. The cradles are slung upon axes, so that the moulds turning over the drains remain in the same position, thus preventing the risk of accident in case the attendant should omit to take them out as they pass him, in which case they only make the circuit with the chain, and are taken out the next time they come round to the floor on which they are required.

The charcoal, after it is removed from the filters saturated with coloring matter, is dried, and then reburnt. The retorts of cast-iron or kilns of clay are so constructed that the charcoal, when at a red heat, does not come in contact with the atmosphere, which would destroy it. The charcoal burners, as arranged by Messrs. PONTIFEX and WOOD, are shown in Vol. I. of this work, page 340, under the article BONE-BLACK. L is a cistern for water, and M a cistern for fine liquor, a pipe from which runs down the house, with a cock at each floor. This is used for washing the impurities off the sugar crystals in the moulds, as before described.

M. ALFRED FRYER of Manchester has been for some time at work with apparatus which, if successful, will greatly alter the sugar manufacture. He believes it is a wasteful mode of procedure to attempt to purify sugar in the colonies, even to the smallest extent, the facilities for doing so here being much greater. His method is designed to dry the cane-juice rapidly down into a hard concrete, and so to import it into Europe. In the concrete form, and almost free from molasses, it will not decompose, and the enormous waste of more than half the sugar will not take place, the loss in the European refineries being considered large at six or seven per cent.

BEET-ROOT SUGAR.—In Germany and France cane sugar is extracted in large quantities from the beet-root. The beet-root is a biennial plant, native to the South and South-west of Europe. It appears to have been introduced into the Netherlands during the possession of that country by the Spaniards, and to have thence passed into France, Schleswig-Holstein, Germany, Sweden, England, *et cetera*. There are many varieties of the beet, but that specially prized by the beet-root sugar manufacturer, and therefore chiefly cultivated in those countries where this branch of industry is pursued, is the Schleswig beet, or white beet—*Beta alba*—called also from its qualities the sugar beet. When the leaf-buds appear above the ground, the leaves thrown off sometimes rise very high before spreading; sometimes they spread almost immediately above the surface of the ground. This variation, which is partly hereditary, partly conditioned by soil and other circumstances, gives rise to a considerable difference in the quality of the sugar which is extracted. For as the thick and upper end of the tapering root is, during the growth of the plant, projected a little above the surface of the ground, the exposed portions are acted upon by the light, and the otherwise white root is thereby turned green owing to the formation of chlorophyll. But where the leaves spread out on emerging from the ground, the root is

shaded and preserved from such colorization. The Quedlinburg beet has a shade of red on its outer coating, and a species of a yellow variety has been recommended on account of the greater quantity of sugar that exists in its juice. The root of the beet contains water, cane sugar, vegetal fibrin, and fat, gum, coloring matter, pectin, together with the carbonates, chlorides, sulphates, nitrates, phosphates, oxalates, malates, *et cetera*, of potassium, sodium, iron, lime, and magnesia. The water varies from eighty to eighty-eight per cent. of the whole root. The coloring matter—twelve to twenty per cent.—contains from five to six per cent. of vegetal fibrin; the remainder is cane sugar, with the other constituents. The length and straightness of the healthy beet points to a deep soil as the one appropriate to its cultivation, while the large quantity of water limits its growth to tolerably moist localities. An over-rich soil, however, is harmful, on account of the introduction into the plant of too much of the mineral constituents. Two or three of the seeds of the beet-root are set by means of a hand hoe, about a quarter of an inch below the surface, at regular intervals of between thirteen to sixteen inches, and covered with earth. If, in consequence of a stormy heavy rain succeeded by dry weather, the surface of the earth becomes so hardened that the young plants are suppressed, and the prospect of a sufficient crop is lost, the land should be reploughed, and a fresh sowing performed. The amount of sugar contained in the beet varies with its size, the smaller plants containing more sugar in proportion than the larger ones.

It has been found that—

Beets weighing $\frac{1}{4}$ pound contain	13	per cent. sugar.
" " $\frac{1}{2}$ " "	11-12	" "
" " $\frac{3}{4}$ " "	8-10	" "
" " 1 " "	6-7	" "

Nevertheless, on account of the greater mechanical trouble of working the smaller beets, the larger are esteemed most. The tapering point of the root and the thick and higher end also contain less sugar than the central portions; this is especially the case with the thick end when it has grown above the ground and become colored by exposure to the light. During the growth of the plant, which lasts about four or five months, the soil must be turned by the hoe four or five times, the first hoeing being performed soon after the appearance of the young plant. The following rotation of crops is said to be favorable for the cultivation of the beet—1. Barley or wheat—with manure. 2. Beet. 3. Oats—three fields being kept under crop. If four fields be employed, clover may be advantageously introduced after the beets.

The beet, as before stated, is a biennial plant. During the first year of its life the root is developed to its full size, and secretes the whole amount of sugar which, in the natural life of the plant, furnishes the material for the growth and maturity of its upper part. It follows that when the plant is cultivated for its sugar, it is for this purpose ripe when its first year's stage of development is complete. The time required for this depends upon that of the sowing, and upon the seasons. Its criterion is the commence-

ment of death in the leaves. When ripe the beet-roots are dug out, the mould gently shaken off, and the heads cut off, together with as much of the root as shows the presence of leaf buds. As the action of light is detrimental even to the exhumed roots, the latter must be covered quickly. If the quantity be small they may be covered with the leaves which have been cut off. It is more usual, however, to pile them in heaps on the ground, to hinder the evaporation of their water, and to protect them from light and frost by covering the heaps with a thin layer of earth. These mounds are sometimes sprinkled with water, which is taken up by the roots, restoring to them their plumpness and crispness which they have lost in a dry season.

The amount of beet root obtained on a given space is, according to BOUSSINGAULT, in—

	On a hectare; kilogrammes.	On an acre; lbs.
Pas de Calais	31,400	27,664
Aisne	25,500	22,770
Nord	35,000	31,226
Somme	24,500	21,859
Eure et Loire.....	8,500	7,570
Seine et Oise	27,250	24,312
Cher	38,000	32,904
Seine et Marne	30,000	26,766
Meurthe—Roville	17,500	15,613
Mean,.....	26,405	23,508

Some roots were examined by RAGSKY and CORENWINDER for their specific gravity—

By RAGSKY.

	I. From Venice.	II. Olmütz.	III. Hungary.	IV.	V.	VI.
Specific gravity	—	—	—	1.050	1.042	1.056
Sugar.....	10.70	—	—	9.4	9.8	8.73
Salts	0.92	0.87	0.85	1.76	0.94	—

By CORENWINDER.

	VII.	VIII. From North of France.	IX.	X.	XI.	XII.
Specific gravity	1.048	1.044	1.045	1.038	1.045	1.037
Sugar	10.00	9.40	8.76	7.90	9.45	8.01

PAYEN gives the following as the chemical constitution of beet root:—

	Per cent.
Water	83.5
Sugar	10.5
Cellulose.....	0.8
Albumen, casein, and nitrogenous matters	1.5
Salts, &c.....	3.7
	100.0

Under salts, *et cetera*, are included malic acid and gum, nitrogenous substances, fatty matters, aromatic substances, coloring matters, essential oil, chlorophylle, malamide, oxalate and phosphate of lime, phosphate of magnesia, chloride of ammonium, silicate, nitrate, sulphate, and oxalate of potassa; oxalate of soda, chlorides of sodium and potassium, pectates and pectinates of

lime, potassa and soda, sulphur, silica, oxide of iron, *et cetera*. The sugar is entirely in the state of cane sugar.

It has been shown, however, that ammoniacal salts do not exist ready formed in beet juice, but are the product of decomposition eliminated, especially when lime is added.—*Michaelis*.

Lactic acid is readily formed by the decomposition of beet root sugar in its juice, and some persons find mannite, although others are not able to do so. A gummy substance is also produced, probably similar to that found in cane sugar refineries, when the sugar has been too long boiled and worked with.

The beet is grown in temperate climates, and it requires a good deal of moisture.

BOUSSINGAULT gave the following analyses of French beets:—

Where grown.	Time of taking from ground, <i>et cetera</i> .	Per cent. of dry matter.	Water.	Sugar.	Ligneous fibre and albumen.	Pectin? added to the lig. matter
Botanic school,.....	Aug. 2.—Roots small,.....	9.5	90.5	5.0	4.5	—
	Sept. 1.—A root of 1100 grammes = about ½ lbs.,.....	7.4	92.6	4.2	2.5	1.0
	Sept. 1.—A root of 460 grammes = about 1 lb. 2½ oz.,.....	9.4	90.6	5.0	2.8	1.6
	Sept. 7.—Root, 700 to 800 grammes,	10.0	90.0	7.3	1.9	0.8
	Young root of 0.3 grammes = 4.6 grains,.....	13.7	86.3	5.9	4.1	3.4
Garden of M. Brongniart,	Sept. 26.—Root from 80 to 100 grammes = 5½ oz.,.....	16.1	84.9	10.0	3.3	1.8
	Oct. 9.—Root, 150 grammes = about 5 oz., ..	14.1	85.9	—	—	—
Vigneux,	Sept. 23.—Root, 500 grammes = 1 1-10th lb.,	16.9	83.1	11.9	3.2	1.8
	Sept. 23.—Root, 700 grammes = 1½ lb.,	13.0	87.0	8.6	2.7	1.7
Grenelle,	Aug. 7.—Root, 300 grammes = 6-10ths lb.,..	15.5	84.5	8.9	6.6	to preceding
	Aug. 11.—Root, 600 grammes = 1½ lb.,.....	12.6	87.4	8.2	2.8	1.6
	Aug. 30.—Root, 1 kilogramme = 2 1-5th lbs.,	13.1	86.9	8.6	3.1	1.4
	Beet in flower, 200 grammes = about 4-10ths lb.,	16.5	83.5	9.8	3.3	3.4
	Beet of two years in seed,	5.5	94.5	0.0	2.5	1.1*
Roville, Meurthe,.....	White beet of Silesia,.....	15.8	84.2	10.6	3.1	2.1
	Leaves of the beet,	6.4	93.6	1.3	3.6	—†

* Add 0.9 of nitre.

† Add 1.5 nitre; the albumen added to the sugar.

The following analyses of ashes of beet are by WAY and OGSTON :—

	Yellow globe.		Long red.	
	Bulb.	Leaf.	Bulb.	Leaf.
Potassa.....	23.54	8.34	29.05	27.53
Soda.....	19.08	12.21	19.05	5.83
Lime.....	1.78	8.72	2.17	9.06
Magnesia.....	1.75	9.84	2.79	9.10
Oxide of iron.....	0.74	1.46	0.56	4.48
Carbonic acid.....	18.14	6.92	21.61	6.11
Phosphoric acid...	4.49	5.89	3.11	4.39
Sulphuric acid.....	3.68	6.54	3.33	6.26
Chloride of sodium	25.54	37.66	14.18	29.85
Silica.....	2.22	2.35	4.11	1.35
	99.96	99.93	99.94	99.96
Per cent. of ash ...	1.02	1.40	1.00	1.91

One ton of beets they calculate, removes from the soil :—

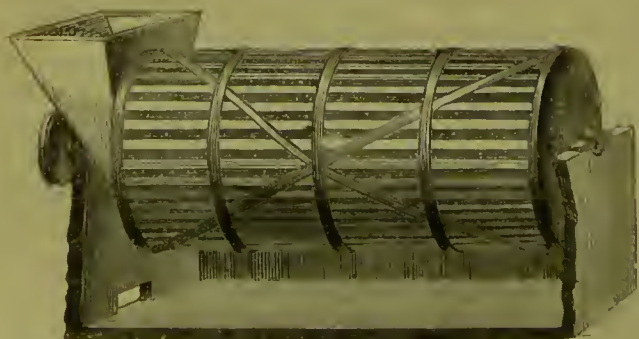
	Mean of three specimens of bulb.	Mean of three specimens of leaf.
	Pounds.	Pounds.
Potassa.....	4.99	7.86
Soda.....	3.02	2.52
Lime.....	0.41	3.31
Magnesia.....	0.43	3.27
Oxide of iron.....	0.12	0.52
Phosphoric acid.....	0.66	1.94
Sulphuric acid.....	0.65	2.20
Chloride of sodium.....	5.29	12.82
Silica.....	0.54	0.76
	16.11	35.20

It has been found that beet with a large amount of juice containing many salts, gives little sugar; either the sugar is not formed, or it is combined with the salts and rendered useless. Manures with a large amount of soluble salts must therefore be avoided; farmyard manure, for example, must not be used in large quantities. Neither a very wet soil nor a very dry one suits the beet root. The Silesian beet is most admired; its juice has a specific gravity of 10° to 15° Twaddell—105° to 107°—and is very pure. It is not a large root.

The amount of juice obtained is from seventy to eighty per cent. of the beet.

The roots, after their extraction from the earth, have to be cleaned and the bruised or diseased portions extracted. For the first purpose they are brought into

Fig. 566.



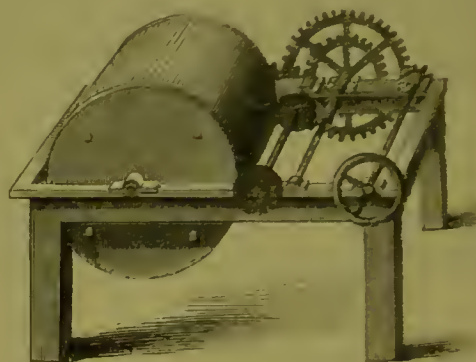
a horizontal cylindrical cage, which rotates round a horizontal axis, and is turned by machinery.

After washing, the roots are examined by women and the unhealthy parts cut out, the smaller side-roots cut off, *et cetera*.

In order that the greatest quantity of juice may be extracted, the roots have to undergo a thorough trituration, the purpose of which is to destroy the cellular texture, and to allow the free escape of the juice. The accompanying figure shows the construction of a trituration mill of this kind.

The macerated beet-root appears as a white semi-emulsive liquid, and contains naturally the white of

Fig. 567.



the constituents of the root. The soluble portion is separated from the insoluble by pressure. Woolen, linen, or, for the reason mentioned in the manufacture of cane sugar, cotton cloths or bags are employed to filter the juice. When cloths are used the process of filtering is as follows :—A plate of iron of the size which the cake is destined to have is placed upon the press-table—below. Around this plate a movable wooden frame is placed, of the appropriate depth. The frame and plate are covered with the cloth, which is smoothed into the edges and corners of the box so formed: the corners of the cloth being of sufficient length to cover the box again when folded back. A measure of the crude juice is then poured upon the cloth smoothed down by the hands, and the corners of the cloth are folded back upon it. The wooden frame is then removed; another plate is placed upon the top of the first cake, the frame adjusted round it, and the same process is repeated. In this way a pile of cakes, inclosed in cloths, is formed, alternating with iron plates. Sometimes, instead of iron plates, a disc of plated osier, or a series of rattan canes lightly bound together is used. The latter contrivances are less likely to break the bags when the pressure is applied, but the juice is not so perfectly expressed as when metal ones are employed. When bags are used they are filled with the juice, the mouth squeezed together, and the whole turned over upon the plate, so that during pressure the mouth is held together.

The piles of cakes are next submitted to pressure, usually that of a hydraulic press. The piston of the press is made to descend and to squeeze the pile between itself and a firmly fixed metallic slab, rather larger than the cakes. The surface of the press table is nearly on a level with the top of the slab. The press table is surrounded by a rim, through one part of which a hole is cut, connected with a pipe for carrying off the juice. It has been proved that the best press is

leave at least twelve per cent. of the theoretically extractable juice in the cakes. A portion of this may be recovered by steeping the cakes which have undergone the first pressure, in a shallow vessel of water, or submitting them to the action of steam, and subjecting them to a second pressure. But even then by no means the whole of the sugar is separated. Moreover, the greater dilution of the juice so produced increases the expense of its subsequent working. Perhaps the centrifugal drying machine may find an application to this end; or perhaps the passing of long bags of the juice through cane crushing-mills might extract the juice more effectually. But the importance of the perfect separation of the sugar is not of so much moment as is the case with canes, because the spent cakes are generally used in beet-root sugar manufactories as food for the cattle employed on the estate, and their value for this purpose is greater the more sugar they contain.

An exhaustive method for obtaining the juice from beets has been proposed, in which the roots are sliced and macerated without destroying the integrity of the slices. The weak juice thus extracted is employed for macerating a fresh portion of slices, and so on until the extract is sufficiently strong for defecation and filtration.

Probably on account of the greater quantity of albuminous matter contained in the beet over that in the cane; in part, also, on account of the greater dilution of the natural sirup—the oxidation and fermentation of the former proceeds more readily. Hence extraordinary care must be taken not only to submit the extract from the beet as speedily as possible to the subsequent operations, but the press table, *et cetera*, must be thoroughly cleaned after each pressing, and the bags or cloths perfectly purified.

The processes for defecating the juice of the beet-root, are so analogous to those already described with the juice of the cane as to need no special description. The seum is submitted to pressure in a screw press, in order to separate the juice which it retains mechanically.

The employment of bone-black, also, resembles almost completely its use with cane sugar. In the beet-root sugar manufacture, however, the filtering cylinders have usually a longer and narrower form than is the case with cane sugar.

Perfectly pure sugar made of beet cannot be distinguished from perfectly pure sugar made of canes; but the imperfectly purified sugars may be distinguished—first, by the analysis as shown in the composition of the juices; and second, by the taste; which is in the case of the beet-root bitter and unpleasant; in the case of the cane sugar extremely sweet, with a pleasant vegetal aroma.

When beet is taken from the ground, it is used at once for sugar; if not used it rapidly germinates, and the sugar diminishes. For this reason SCHUETZENBACH introduced the method of slicing the beet in small pieces and drying it rapidly. When dry it may be preserved. When this plan is adopted, the manufacture may be carried on during the whole year, instead of during a few months only, or from October to March.

By the process of SCHUETZENBACH three hundred kilogrammes of beet are dried every twenty-four hours on a square metre, losing eighty to eighty-four per cent. of their weight. When used it is dissolved into a juice containing thirty-eight to forty-two per cent. sugar at 42° Twaddell, so that there is much less of water to be evaporated than with the green juice. The dried beet is macerated in a closed vessel.

100 kilogrammes of beet give 18 kilogrammes dried beet.

	Francs.
40 hectolitres of coals, at 1.50 francs for a hectol., } 60	
dry, 40,000 kilogrammes of beet	
20 days of a woman's wages at 80 cents	16
14 days of a man's wages at 1.5 francs	21
Interest on the kiln—costing 14,000 francs—for 9 days, at 7 per cent.	11
	108

100 kilogrammes of dry beet cost 11 francs 11 cents.

M. SCHUETZENBACH has now made an immense establishment in Galicia. It is calculated to produce forty million kilogrammes of sugar yearly. There is a central sugar refinery and fourteen drying establishments in a circle of seven leagues, in order not to carry the wet beet far. He obtains a dry produce containing fifty per cent. of sugar. It is dissolved in closed vessels, and gives a juice of 52° Twaddell. He obtains six per cent. of sugar from the root. Such an establishment keeps a large circle of ground occupied.

It has been said that it is better to cut the beet into cubes. This plan is not adopted at Waghäusel, one of the most complete establishments, and certainly their slices being thin must dry readily. The plan adopted there is to dry for preservation; this is done in six hours on the wire gauze. Then when making the solution, it is at first obtained at 32° Twaddell, and boiled in vacuo down to 41.5 Twaddell, lime water added, boiled half an hour to remove ammonia, and kept alkaline with lime.

The establishment of Waghäusel, near Carlsruhe, employed in 1855 three thousand people; twelve hundred of these were in the drying department. One drying department was at the works, and six others at different distances. The works covered twenty-five morgen of land—about twelve acres. There were in it one hundred horses, one hundred cattle, and from thirty to forty pigs. A hundredweight of raw roots cost the establishment seven-pence. There were nine cylinders for refined sugar, and thirteen for commoner, twelve feet by six. There were twenty infusing vessels, twelve to fourteen feet deep and seven wide. The dry beet contained forty-six to forty-seven per cent. of sugar. Five per cent. were lost in making; by the old way the loss averaged eleven per cent. The capital was about eight million francs.

Maple Sugar.—In the Western State of North America, a great portion of the sugar required for home consumption is extracted from the maple. The season at which the collection of the juice takes place is the early spring—February, March, and April, when a light snow is on the ground. The trees most fit for tapping are those which have reached the age of twenty to thirty years. At the south side of such trees two or more holes are bored about four or five inches apart, three-quarters of an inch in diameter, and about two feet above the ground. The holes run

radially into the tree, and are inclined upwards, penetrating the inner white bark to a depth of about half an inch. Into these holes tubes of elder-wood are inserted. The upper portion of the part of each tube which is in the tree is slit off, so that it forms a semicylindrical canal or trough. Troughs are placed below the projecting ends of the tubes to receive the juice as it flows out. The average yield of a tree is about one quart in twenty-four hours. A tree may be tapped for twelve years in succession, the average yield being between two and three quarts annually. The crude juice is usually boiled down without defecation or filtration in copper cauldrons, which may contain fifteen or eighteen gallons. When the examination of the concentrated juice shows incipient crystallization, it is poured out into shallow moulds, about two inches in depth. When set, the sirup is usually ladled out of a depression made in one portion of the cake. This maple-sugar sirup, which corresponds to the molasses of cane-sugar, is, however, more highly prized than the sugar itself; it has a delicate aromatic smell and taste, and is greatly sought for making confectionery. The sugar sells at the rate of fourpence per pound. Some years ago enough cake maple-sugar was manufactured in the State of Vermont to inclose the whole State with a wall of sugar eight inches high, and eight inches in thickness. The North American Indians push the evaporation of the juice rather further than the whites, and after the removal of the sirup, the cakes are chopped up for the market.

SUGAR OF STARCH AND WOOD.—Crystallizable sugar is converted by boiling and by acids into glucose or grape sugar, a substance difficult to crystallize. Sulphuric acid converts cellulose, inulin, starch, sugar of milk, straw, sawdust, and such materials, into dextrin and sugar. BRACONNOT obtained from 20.4 of rags 23.3 of dry sugar. Cotton and linen being nearly pure cellulose, would give more than sawdust; about one hundred and forty parts of strong acid are used to one hundred parts of cellulose of rags, cotton, *et cetera*. The change is at first into dextrin—see STARCH—then into the sugar.

Sugar is made from starch by boiling it with water acidulated with one per cent. of sulphuric acid. The conversion takes place in half an hour. The amount of starch is about fifty per cent. of the water. At the same time the quantity is varied, as given by KNAPP that two and a half of sulphuric acid is used to one hundred of starch, and three hundred to four hundred of water. Makers are not precisely agreed as to the time, but it is different according to different degrees of solution. The sulphuric acid is removed by lime. The juice, clarified, is boiled down to 105° Twaddell, and crystallized in flat vessels. Crystallization commences in about a fortnight. The sugar is then drained and dried. This sugar is seldom sold as such. It is manufactured for conversion into alcohol.

The conversion of cellulose and starch into sugar, by the action of sulphuric acid, giving to them some of its water, may be better understood by examining the composition of both, as already given.

CAUSE OF THE LOSS IN THE MANUFACTURE OF CANE-SUGAR.—*Decomposition of the Juice.*—The albu-

minous matter in the juice is the chief if not the only cause of its rapid decomposition, and this is promoted by a heat which is not less than 80°, as the liquid flows from the crushing mills. Lactic acid in the case of beet juice is abundantly formed, and a viscous substance which has no sweetness. At the same time, also, there is formed a little mannite. An enormous loss of sugar is known to occur from this change of the juice. The one to two per cent. of alkaline salts can scarcely be said to act prejudicially to any extent. There is no known way of removing them.

To prevent the decomposition of sugar, especially in the case of Colonial juice, in warm climates, it is important to use an antiferment. PROUST proposed sulphite of lime in 1810; and DUBRUNFAUT took a patent for using sulphurous acid in 1829. MELSENS of Brussels has lately proved the great value of bisulphite of lime in the manufacture of beet-root sugar. The use of this is becoming general for beet-root. It would, no doubt, be found still more valuable in the Colonies, if no unlooked-for harm was occasioned: although care must be taken not to send the sugar over with sulphites in it. The bisulphite of lime resists the coloring of the juice, and even removes some of the color. Acids readily remove the color of sugar; but such color returns as soon as neutralization takes place. MELSENS believes that by means of this salt he will be able to reduce the molasses so much, that he will be able to remove the salts in solution in it as now, but by taking out ninety per cent. in a crystalline form, he will return the most of the salts to the earth. The small amount of molasses left could be returned to the pressed out beet before using it as food for cattle. The bisulphite of lime does not destroy the quality of the beet as food. LUDERSDORFF prefers sulphuric acid, afterwards to be neutralized by lime.

It is well to add that a French commission examined the action of bisulphite of lime on cane juice in Guadeloupe, and found that the amount of good well-grained sugar was diminished by it. If they used it as acid, as some do, it is not surprising.

KUHLMANN proposed to prevent the decomposition of sugar by adding an excess of lime, and then throwing it down with carbonic acid. This is again brought forward by M. ROUSSEAU. Three to four times the usual amount of lime is added, making a sugarate of lime; when the juice has reached 131° Fabr. the lime is added, mixed with six times the amount of water; the temperature then is raised to 180° or 190°, and the liquid filtered. Carbonic acid is added, a voluminous precipitate takes place, and the juice is now put on the charcoal filter without removing the chalk. M. ROUSSEAU had it brought before a commission of the French Academy, which reported a favorable result, but considered that the alkalies would act injuriously on the compounds of lime and organic matter not precipitated. To avoid this ROUSSEAU adds ammonia, which is converted into carbonate. The carbonate of ammonia decomposes the combination of the lime, and carbonate of lime is thrown down, leaving ammonia free. But this addition of ammonia is no improvement, and indeed the whole objection is a most uncertain one.

KUHLMANN believes that the free alkaline salts are hurtful, but has found it impossible to remove them by means of strong acids, or by sulphate of magnesia, sulphate of ammonia, or chloride of ammonium. He prefers phosphate of ammonia.

This process—one cannot speak for the phosphate of ammonia, but only for the carbonic acid—is a good deal used in France.

MAUMENÉ says that if lime is added in quantity sufficient to form three of lime and one of sugar— $3 \text{ CaO C}_{12} \text{ H}_{11} \text{ O}_{11}$ —the sugar is preserved, and nitrogenous matter falls with the lime. However this may be, if boiled with the lime the color is rapidly deteriorated.

Precipitation.—Attempts have been made to precipitate sugar from its solutions. DUBRUNFAUT and R. DE MASSY have a process depending on the union of sugar with baryta. Caustic baryta is added to the sugar till it is all thrown down. A pure compound of baryta and sugar falls, and this is decomposed by carbonic acid. It is not at all proved that all the sugar can be thrown down in this way; it is said only to be done at a boiling heat. NICKLÈS says it cannot be done with uncrystallizable sugar.—See further in accounts of *Patents*.

USES, PHYSIOLOGICAL EFFECTS, AND IMPURITIES.—Sugar exists in the juices of many plants, and is in part the food of many animals. As an article of food it has highly fattening properties, and as such it must be considered as serving mainly for the production of warmth in the body. Animals which eat it appear sleek and comfortable, and it tends to promote digestion. At the same time there are many persons who cannot use it as food to any great extent, on account of its inclination to produce acidity. The negroes, and even whites, who suck the sugar cane are not found to be troubled with these symptoms, whilst the teeth of the negro never suffer from the constant use of the sweetest liquids. Such, however, is not the case in England, where a great amount of sugar is found to be hurtful to the teeth. It is perhaps scarcely correct to say this of sugar in the diet, as it is not well known that the same effects would be produced by sugar used in abundance—in pies, for example—as would be produced by sugar taken alone and long retained in the mouth. Persons engaged in sugar works are in the habit of eating sugar very frequently. With some it is a part of their duty, as the value is to some extent measured by the taste; but whether as a duty or a pleasure, such persons are almost invariably doomed to lose their teeth at an early period. It may be said that sugars, until dried or thoroughly crystallized, have a certain amount of acidity in them; but this is in general too small to stand as a reason: much more acid is taken in other species of food. There can be no doubt that sugar in large quantities peculiarly affects the digestive organs, and causes also a distinct taste, other than sugar, to be perceptible some time. The cause may be that as an article of food it does not associate well in large quantities with the food used in this country. But, again, its valuable qualities are many, and the amount fitted for individuals must be found by experience.

The excessive use of sugar, that is, to the extent, with a healthy man, of about a pound per day, produces effects not apparently much studied. One effect is a tendency to giddiness, without any observed additional inconvenience. It is possible that this may arise from the large amount of carbonic acid generated during its decomposition, causing at the same time frequent eructations.

When the throat is irritated, a solution of sugar slowly flowing over the surface prevents irritation and allays coughing. Sugar and treacle are valuable for covering burns, acting chiefly, as Mr. CROMPTON of Manchester believes, as non-conductors of heat. It is sometimes used in a powdered state for ulcers or rather proud flesh, and for specks on the cornea. It has a considerable power of reducing metallic oxides, and has been used as an antidote for poisoning by metallic salts, such as those of copper; mercury, silver, gold, and lead may be included; but this action has been referred more to its physical than to its chemical properties. It is highly antiseptic, no doubt, because it covers from the atmosphere. It is much used in pharmacy for imparting flavor to bodies, and to conceal taste. It is also found useful for giving form and consistence to some medical substances. It is employed as a medium of bulk to convey smaller substances, as in opium, lozenges, *et cetera*, and notably so by the homœopaths, whose medicines may sometimes be distinguished from sugar. Many animals delight in it. Horses put their noses into the sugar bags, and even suck them, whilst the fowls fight for the fallen pieces.

Sugar is also employed for fermentation. Indeed, properly speaking, it is the only thing used for fermentation; but sugar from the cane, and still more the less crystallizable portion, is now considerably used. It has been employed for the purpose of making oxalic acid by oxidation with nitric acid; but starch or cheaper substances are more commonly employed. Enormous quantities are used in preserving fruits. Preserved fruits are becoming daily more and more accessible and more used. Formerly fruit was preserved only by such careful and well-to-do housewives as could spend some considerable time and money on the luxury. Now the conservation forms a branch of industry or manufacture. Marmalade and preserved oranges are sent from Scotland in great quantities, and are everywhere prepared. Preserved fruit is also sent from various parts of Europe, especially the shores of the Mediterranean, and it has begun to appear at our dessert tables after arriving from the East and the West Indies. England, as usual, takes up this manufacture with great vigor. One house made a small experiment last year with thirty tons of preserved plums, and finding it successful made next year a hundred tons. The preserves were of an excellent kind, and cheaper than those made by the usual methods in smaller quantities.

The amount of sugar used in the form called sweetmeats, confits, and bonbons is very great, and more so on the Continent, according to accounts, than here. At the same time, although one finds in France, Germany, and Italy some very handsome confectionery shops, it strikes the Editor that the amount of confits in

them is very small, and the variety very limited. The sugar may be pure and unadulterated with arsenic and sulphate of lime, or any other noxious or poisonous substance; but the shops seem to depend a good deal on their sale of beverages, and in some places on their restricted number. No country offers such great varieties of excellent sugar sweetmeats as England, or in such rich diversity. In China the variety is said to be very great. The only fault in England is that there exist so many qualities to suit the purses of every man, rich and poor. The inferior qualities are mixed with flour. This, of course, diminishes the sweetness. This would be a small evil, if the makers did not sometimes use instead of flour sulphate of lime or plaster of Paris. Even this, however, is innocent in comparison to the coloring matters used at times. Sweetmeats are colored by ignorant people with common paints of any kind that come in the way. These are painted roughly on the sugar. Some of them contain copper, some arsenic and copper, and some lead. Several cases of death have occurred from the use of such substances; and there can be no doubt of the propriety of a surveillance over the manufacture or sale of articles liable to be so abused. The best confectioners use only innocuous colors, and these vegetal.

The unfiltered sugar, or Muscovado, as it comes from the Colonies, contains many impurities, and should never be used. Many peculiar species of beetles are found in it. One especially infests abundantly all sugar-houses. But the *acarus sacchari* is the animal that, of all others, is the most to be avoided; it is not found in filtered sugar. It is an animal somewhat like an itch insect, and a drawing would not be pleasant in an article on sugar. The grocers' itch is in all probability produced by the handling of Muscovado sugar, and the attacks of this insect. Dr. HASSALL advises the use of refined sugar only. The Editor is able to state that, in Lancashire at least, purified or filtered sugars, of various shades of color, are everywhere to be had, and they are as free from insects as the purest white lumps.

Sugar itself for domestic purposes is not now adulterated, or very rarely. There was a time when sand was used to adulterate the brown qualities; but such a practice would not now be tolerated for a moment. A very ingenious adulteration came into vogue for a while; but the Editor believes it is not resorted to now. It was the custom of using starch, or starch made into gum. When this is used in tea or coffee it is not readily distinguished from true sugar. If starch is employed it is readily found by dissolving the sugar in cold water, in which the starch is not soluble. If British gum be used it is less easily detected; it has small granules, not hard and crystalline like those of sugar, and is soluble in cold water. It also becomes gummy in drying, instead of becoming sirupy, and then crystalline like sugar. This adulteration cannot be made with pure white sugars. A microscope assisted by an ordinary good taste is perhaps the best guide to its discovery. The most general use of sugar is for sweetening tea, coffee, and chocolate; but it is also largely used in sweetening mixtures of strong drink, as well as in numberless

articles of cookery. Its abundant introduction into Europe has changed the whole system of cooking and must have largely assisted in rendering food pleasant in an age when the arts of peace have somewhat taken away the violence of appetite which is connected with rude times, and is satisfied more with quantity than quality. For the poor especially is this remarkably true.

A LIST OF SOME OF THE LATER MORE INTERESTING AND CURIOUS INVENTIONS RELATING TO SUGAR, WITH REMARKS:—

1845.—JAMES JOHNSTON patents an ingenious plan of emptying a vacuum pan without destroying the vacuum by a pipe twenty-five feet long. He also has the sugar running down an inclined plane whilst in the vacuum.

FREDRICK GYE presses sugar into suitable forms for use.

1846.—RICHARD WRIGHT patents exposure to hydraulic pressure and steam.

1847.—JAMES JOHNSTON patents polygon shaped sugar moulds, cast-iron crystallizing pots coated with tin, zinc, or enamel. The latter would be good if the enamel did not break off into the sugar.

H. K. CLAYPOLE.—Saving fuel with two generators like locomotive boilers, heated by a fire that first passes over three open boilers. A current of high pressure steam to make a draught. A hot iron tube heated by steam in the clarifying boiler. A canal in the teache for running out sugar. Galvanized iron coolers. These are for the Colonies.

JOHN SCOFFERN.—Combined use of lead and sulphurous acid as separately described.

1848.—J. A. STEINKAMP patents the use of cotton in small pieces of one-eighth to one-fourth of an inch for clearing sugar.

1849.—JOHN OXLAND patents acetate of alumina boiled with sugar at 220° till the acid is removed. The alumina remaining is removed by tannin and a little carbonate of lime.

REECE and PRICE patent hyposulphites with alumina or acetate, hyposulphite of alumina, and various hyposulphites and sulphides of magnesium to precipitate lead. Also hyposulphites and sulphurous acid to remove the sulphide of hydrogen which has been used for removing lead. The bicarbonate of lime for defecation and many other things.

A. V. NEWTON.—Bones dissolved in sulphurous acid for completely extracting the crystallizable sugar. Other antiseptics, as mustard, creosote, horseradish, nitrous acid gas, with or without salts of iron or other salts. Tannin, lampblack saturated with creosote, products of the distillation of certain albuminous matter, tars, wood essence of turpentine, aldehyde, and analogous bodies, chlorine combined with oxygen. Separating ninety-seven per cent. of pure sugar by baryta, and decomposing by carbonic acid or sulphurous. Oxide of strontium, it is said, requires a long time; oxide of lead does it imperfectly. The process gives fifty to sixty parts of hydrate of baryta to one hundred of sugar. Still the sugarate obtained contains fifty per cent. sugar, twenty-two baryta, and twenty-eight water. It is decomposed by a solution of twenty-five quarts of water and twenty-eight pounds of sulphuric acid. It may be

washed till the solution has the strength of 23° to 31° Twaddell. If lime is used, twenty-eight per cent. is taken. The sugarate is filtered out in TAYLOR's filter, or in presses warmed to 100°; it contains five equivalents of base to one of saccharic acid.

The baryta does not offer to be cheaper than animal charcoal, and baryta, at least as a soluble salt, is no less dangerous than lead, whilst it is not so easily detected. Several patents have been taken for removing the baryta, but on this point, the last traces excepted, no difficulty has been found.

C. W. FINZELL—Patent to introduce steam to clear the sieve of the centrifugal machine.

1850.—JOHN SCOFFERN makes a valve of elastic material over a perforated tube.

GEORGE GLYNNE grinds sugar with litharge, and makes a saccharide of lead.

Sugar is a very tender substance chemically. It is easily destroyed. It also readily dissolves many substances. As little of any substance should be added as possible, and as little heat should be given and as little motion.

D. T. SHEARS makes loaf sugar at once on boiling down the juice; purifies sugar by alkaline liquids and sulphurous acid gas; uses also lime and a West Indian plant called *wassama*. Puts a *rouser* in the vacuum pan for stirring round.

HERMAN SCHRODER—a combination of revolving discs on pipes heated by steam to evaporate the sugar.

1851.—R. and J. OXLAND.—When acetate of lime is used, remove by superphosphate of lime or lime. Aluminate of lime to defecate, or phosphate of alumina.

R. A. BROOMAN—Centrifugal apparatus in a vacuum pan; centrifugal drum for evaporation; centrifugal apparatus for cleaning charcoal.

1852.—HENRY BESSEMER.—The claims in this patent being nineteen, are too numerous to mention, and so complicated as to require an article for themselves. It is believed that they rather tend to load a refinery with machinery. Invention will rather simplify the machines, or altogether dispense with some of them; but there are good and ingenious thoughts amongst those of Mr. BESSEMER worth studying, although not as yet found successful.

R. A. BROOMAN.—Endless bands for carrying the sugar to be cleansed.

ROBERT GALLOWAY.—Using plumbite of lime instead of lead.

R. W. LIENIER.—Patent for applying sulphurous acid to the pulp of beet-root or cane before boiling it, adding excess of lime. Use of vessels of wood, slate, stone, glazed metal, or earthenware for boiling juice.

WILLIAM MILLER.—For never allowing the sugar to come in contact with metals; evaporating by surfaces formed of cloth or textile fabric.

BROOMAN.—Removing excess of lime by soap.

GERD JACOB BENSEN.—Hot air passed through the sugar to dry it. Crystallized sugar placed in a vacuum pan. Crystals thus got are mixed with a clear sirup produced from refined sugar; the mixture put into moulds and stored.

In 1852 J. BRANDEIS took a patent for removing lead from sugar by animal charcoal, thus being able to use lead to purify sugar. The Editor believes that the destruction of the animal charcoal soon follows. The oxide of lead, on heating, melts in the pores. This, although possible, would be very expensive.

JOHN ASPINALL proposed lifting the sugar solution in thin layers on an endless band of wire gauze, exposing it to heated air, and drawing off the water. This has not been much used. Even thin layers of sugar may become covered with a pellicle not easily broken. HOWARD's vacuum pan, by keeping up ebullition, allows no hard surface to prevent evaporation. This, however, may be the germ of something good not yet completed.

JAMES HADDEN YOUNG presses sugar between two unyielding surfaces, one of them perforated; he uses a vacuum. The beet-root system is a similar one, but mechanical pressure is used.

HENRY BESSEMER also proposed contact of warm air, raising the sugar in thin layers on screws or discs instead of on wire gauze, as Mr. ASPINALL. He proposed also in his patents to use wooden troughs for crystallizing, and to moisten the crystals with a deliquescent compound of sugar and chloride of sodium, or with gelatine, glucose, or molasses. He adds, also, the use of hot water instead of steam to heat sugar, and warm air below 212°, and tinned vacuum pans. Tin is too easily dissolved. What might be more useful than any of the above is the enamelled vacuum pan, if such large vessels could be covered with enamel.

GEORGE DIXON has a number of perpendicular tubes, in which is placed the sugar and heated by steam; but there is a want of exposure for evaporation. Perpendicular tubes are found to heat the sugar more equally.

JEAN BAPTISTE MOINIER allows the sirup or liquid to fall over spheres, thus obtaining surface, and he allows it to descend from amongst the spheres, and exposed to warm air.

1853.—WILLIAM PIDDING patents hydrate of alumina, or silica, or a mixture incorporated with a fatty acid, and adds a little oxide of iron. He seems to wish to include the impurities of the sugar in a kind of fatty salt or soap. This answers for some liquids, but the iron will not improve sugar.

FRANK CLARK HILLS removes the lead from sugar by filtering through sawdust, or by dissolving it out with nitric or acetic acid. Animal charcoal much treated with acid soon loses its texture.

LORD HOWARD DE WALDEN cleanses crystals by hot air and steam. This is, in fact, bleaching with the atmosphere. Air bleaches many substances, but the Editor has not heard if it has been found to act favorably on sugar.

CONRAD W. FINZELL.—Defecation in vacuo. Not yet proved to general satisfaction to be of any benefit.

MANIFOLD, LOWNDES, and JORDAN—Reducing the cane to sawdust, then dissolving the sugar out by steam. This does not seem the right direction, as the great loss is in reality in the juice; it is not left in the cane.

JAMES MAGELSTON—Atmospheric pressure to remove crystals from sugar. This is in fact equal to a vacuum.

ROBERT GALLOWAY—Removing lead by tannic, gallic, and pectic acids, or the soda and potassa compounds.

JOHN and J. E. A. GWYNNE dry beet on an endless band, in one heated eyelinder after another.

JOHN THOMAS WAY—Soluble silica to remove the excess of lime in defecation; filtering through a bed of Surrey silica or sand. This would add another operation, as it is supposed it would still require to be passed through the bag filters.

EDWARD BEANS puts the beating tubes into his vacuum pans vertically, and filters through a false bottom covered with sand, powdered flint, or road sweepings.

1854.—CHARLES H. COLLETTE proposed to defecate with lime and superphosphate of lime.

JOSEPH BOUR evaporates by a series of hollow vessels revolving in sirup and internally heated by steam; very much used, especially in the Colonies.

JAMES WRIGHT makes a centrifugal machine, where the outer case revolves with the inner, and a partial vacuum is formed to help the drainage of the liquid without the air-pump.

JOSEPH NASH adds an air-pump to his charcoal filters; fills the centrifugal machine without stopping.

W. A. ARCHIBALD consolidates sugar by exposing to cold air and agitation.

D. T. SHEARS—Another plan for filling and emptying the centrifugal machine without stopping.

PIERRE ANDRÉ DECOSTER has a patent for cutting up the canes; he then presses and mashes by centrifugal power.

L. WRAY wished to take a patent for making sugar from *Holcus saccharatus*, called *imphée* on the coast of Africa. Refused.

1855.—R. A. BROOMAN.—A filter of cotton or other fibre between two perforated plates or frames.

JAMES STEELE says that the pin at the apex of the sugar mould is now inserted to make an outlet for the drainage. He inserts it at first, and draws it out when it is desired. A cavity is thus left which assists in drainage. By the insertion of a pin too large a hole is made.

There are many patents for the mode of cutting up sugar into lumps.

JOHN ASPINALL drives the sugar in at the apex of the cone, burning it out at the top.

C. W. FINZELL's patent for the use of NEEDHAM and KITE's apparatus in the filtering of sugar. It is the combination of grooved plates or planks, with filtering cloth, which is laid between two.

ALEXANDER W. ANDERSON precipitates sulphate of copper by tin, and obtains sulphate of tin for sugar refining; then precipitates tin by lime. Removes tin from the sugar at last by animal charcoal.

GARTON and PARSONS.—To treat sugar for distilling they add sulphuric acid, and keep the liquid at 140° for five days, then remove by lime.

STATISTICS OF THE UNITED KINGDOM.—The following, from Messrs. REID's circular, of Liverpool, with alterations, will give some interesting details relating to the United Kingdom:—

Sugar being an article of luxury rather than a necessary of life, the extent of its consumption is affected by the condition of the people as well as by market value, and any increase from the first of these causes is a satisfactory indication of prosperity. Reverting to the early years of the present century, one finds that a long continuation of high prices in addition to periodical privations among the laboring classes gradually reduced the average consumption in the United Kingdom from twenty-two pounds per head in 1801 to sixteen pounds in 1844. A combination of favorable circumstances then arose to cause a reaction; the duties were greatly reduced; production increased; prices ruled low; and an enormous influx of gold commenced pouring into the country, thereby so largely adding to the means of procuring extra comforts and luxuries, that the average consumption per head more than doubled during the last fifteen years.

CONSUMPTION AND IMPORTS.—The following statistical table, made up as far as possible from official returns, will more particularly show the changes which have taken place. The figures for the present year are only approximate, as the return had not been made out when the tables were calculated. The prices and duties quoted are for West Indian Muscovado:—

Years.	Population of United Kingdom.	Consumption of Sugar.		Prices and Rates of Duty.			Duties paid on all Descriptions.	Per Head.
		Total Tons.	Lbs. per Head.	Gazette Average Price.	Rate of Duty.	Total per Cwt.		
1801	16,371,554	159,916	22	59s. 5d.	20s. 0d.	79s. 5d.	23,066,163	3s. 9d.
1811	18,548,476	187,092	23	39s. 8d.	27s. 0d.	66s. 8d.	4,652,824	5s. 0d.
1821	21,302,392	170,612	18	33s. 2d.	27s. 0d.	60s. 2d.	4,188,997	3s. 11d.
1831	24,319,811	203,812	19	23s. 8d.	24s. 0d.	47s. 8d.	4,650,606	3s. 10d.
1841	27,021,949	202,899	17	39s. 8d.	25s. 2d.	64s. 1d.	5,114,390	3s. 9d.
1851	27,721,921	328,581	26	25s. 6d.	13s. 3d.	38s. 9d.	3,979,141	2s. 10d.
1859	30,000,000	450,000	33	27s. 0d.	12s. 0d.	39s. 8d.		

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859.

	1841.	1842.	1843.	1844.	1845.	1846.
Sugar Raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,057,617	3,868,334	4,028,231	4,129,345	4,779,317	4,617,509
Of or from foreign countries	261	103	76	98	77,307	602,739
Total of raw sugar	4,057,878	3,868,437	4,028,307	4,129,443	4,856,624	5,220,248
Sugar refined and sugar candy	22	37	19	6	56	18,408

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859—*continued.*

	1847.	1848.	1849.	1850.	1851.	1852.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,805,489	4,921,332	5,409,209	5,183,097	4,854,506	6,216,341
Of or from foreign countries	974,019	1,220,964	496,478	908,395	1,379,041	682,526
Total of raw sugar	5,779,508	6,142,296	5,905,687	6,091,492	6,233,547	6,898,867
Sugar refined and sugar candy	26,130	46,191	75,137	116,335	338,079	273,991

	1853.	1854.	1855.	1856.	1857.	1858.	1859.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	5,740,854	5,589,467	4,934,343	5,695,363	5,325,975	5,323,580	5,458,380
Of or from foreign countries	1,531,979	2,439,291	2,319,879	2,065,877	3,064,721	3,775,300	3,552,420
Total of raw sugar	7,272,833	8,028,758	7,254,222	7,761,240	8,390,696	9,098,880	9,010,800
Sugar refined and sugar candy	214,756	303,649	287,520	187,211	329,122	262,460	386,820

UNITED STATES.

CONSUMPTION OF FOREIGN AND DOMESTIC CANE-SUGAR, FOR THE YEAR ENDING 31ST DECEMBER IN TONS.

Year.	Foreign.	Domestic.	Total.
1859 ..	239,034 ..	192,150 ..	431,184 ..
1858 ..	244,758 ..	143,634 ..	388,492 ..
1857 ..	241,765 ..	39,000 ..	280,765 ..
1856 ..	255,292 ..	123,468 ..	378,760 ..
1855 ..	192,604 ..	185,148 ..	377,752 ..
1854 ..	150,854 ..	234,444 ..	385,298 ..
1853 ..	200,610 ..	172,379 ..	372,989 ..
1852 ..	196,558 ..	118,659 ..	315,217 ..
1851 ..	181,047 ..	107,438 ..	288,485 ..
1850 ..	143,045 ..	126,421 ..	269,466 ..

Average increase for the ten years, 63 per cent.

Oregon and California not included.

PRODUCTION OF CANE AND MAPLE SUGAR IN THE UNITED STATES FOR 1850.

	Cane-sugar in hogsheads.	Maple-sugar in pounds.
Maine,	—	87,541
Missouri,	—	171,943
Maryland,	—	47,740
Alabama,	28	—
New Hampshire,	—	1,292,429
Vermont,	—	5,149,641
Massachusetts,	—	768,598
Connecticut,	—	37,781
New York,	—	10,310,764
New Jersey,	—	5,886
Pennsylvania,	—	3,178,373
Virginia,	—	1,223,905
North Carolina,	$\frac{1}{2}$	27,448
South Carolina,	150	200
Georgia,	1,273	50
Florida,	1,741 $\frac{1}{2}$	—
Mississippi,	278 $\frac{1}{4}$	—
Texas,	7,017	—
Arkansas,	—	8,825
Tennessee,	—	159,888
Ohio,	—	4,521,613
Michigan,	—	2,423,897
Indiana,	—	2,921,638
Illinois,	—	246,078
Iowa,	—	31,040
Louisiana,	262,486	—
Kentucky,	—	386,233
Wisconsin,	—	661,969
Minnesota,	—	2,950
	272,974	33,677,061

This has much increased. Louisiana produced in 1858 three hundred and sixty-two thousand two hundred and ninety-six hogsheads, at sixty-nine shillings per hogshead, and value of twenty-four millions, nine

hundred and ninety-eight thousand, four hundred and twenty-four dollars. A hogshead is half a ton. Total Maple sugar produced in 1859 is believed to be twenty-seven thousand tons, or sixty millions four hundred and eighty thousand pounds.

The annexed extracts from the commerciale review of Messrs. DE CONINCK, Brothers, and Company, furnish some interesting particulars of the statistical position of sugar in France.

The importation of foreign sugar into that country rose in 1859 to eighty-two thousand tons against forty-five thousand tons in 1858, and sixty-five thousand tons in 1857.

From the Colonies, France received last year five thousand tons more than in 1858; while the manufacture of indigenous or beet-root sugar produced in the season 1858-9, was one hundred and thirty-two thousand tons, being twelve thousand tons in excess of the first estimates. During the last six years, the quantities received by France from her Colonies were as follows:—

113,000 tons in 1859	95,400 tons in 1856
108,000 tons in 1858	89,000 tons in 1855
92,100 tons in 1857	82,000 tons in 1854
99,500 tons in 1847.	

The sources of these supplies are subjoined:—

QUANTITIES STATED IN TONS OF 1000 KILOGRAMMES.

	Guadeloupe.	Martinique.	Reunion.	Cayenne, &c.	Total.
1859 ..	24,400 ..	27,900 ..	58,600 ..	1100 ..	113,000
1858 ..	29,500 ..	27,400 ..	52,000 ..	— ..	108,900
1857 ..	18,500 ..	22,300 ..	51,000 ..	300 ..	92,100
1856 ..	21,600 ..	26,600 ..	57,000 ..	200 ..	95,400
1855 ..	21,000 ..	18,500 ..	49,000 ..	600 ..	89,000
1854 ..	22,001 ..	24,300 ..	35,700 ..	— ..	82,000

The consumption of sugar in France in 1859 is thus estimated:—

	Tons.
Sugar—Indigenons.....	120,000
" From French Colonies.....	95,000
" " "	60,000
Total	275,000
Deduct export of refined sugar.....	52,000
Remains for consumption in France.....	223,000

The season of 1858-59 produced of indigenous sugar—

132,600 tons against 150,000 tons { 1857-58
 1856-57
 1855-56

It is not thought that the quantity produced in the season 1859-60 will exceed that of the preceding one, *videlicet*, one hundred and thirty-two thousand tons.

ZOLLVEREIN CUSTOMS RECEIPTS ANNUALLY FROM 1834 TO 1857, BOTH INCLUSIVE.

Years.	Total population of the States of the Zollverein.	Gross receipts in account of export, import, and transit duties.	Average sum per head of the population, derived from custom dues, et cetera, tax on beet-root.
		Rix-dol.	Groschen. Pf.
1834 ..	23,478,120	14,815,723	18 11
1835 ..	23,478,120	16,880,180	21 7
1836 ..	25,150,216	18,462,873	22 0
1837 ..	25,150,898	17,997,295	21 6
1838 ..	25,048,970	20,419,287	23 6
1839 ..	26,048,970	20,869,488	24 0
1840 ..	26,048,091	21,606,191	24 11
1841 ..	27,142,116	22,255,204	24 7
1842 ..	27,578,730	23,653,269	25 9
1843 ..	27,623,815	25,720,761	27 11
1844 ..	28,498,136	26,778,300	28 2
1845 ..	28,499,566	27,721,436	29 4
1846 ..	28,508,436	26,569,214	28 3
1847 ..	29,461,381	27,552,996	28 3
1848 ..	29,460,761	22,699,299	23 6
1849 ..	29,461,628	23,649,730	24 7
1850 ..	29,800,063	22,948,800	23 8
1851 ..	29,800,063	23,256,058	24 11
1852 ..	29,800,063	24,649,721	26 6
1853 ..	30,492,792	22,016,154	23 10
1854 ..	32,559,173	23,157,407	24 9
1855 ..	32,559,164	26,323,272	27 9
1856 ..	32,721,344	26,156,450	28 0
1857 ..	32,940,780	26,595,788	29 5

FROM 1ST NOVEMBER, 1858, TO 31ST OCTOBER, 1859.

To Liverpool	about 3218 tons.
To the Clyde	" 2240 "
To London	" 1614 "
To West of England	" 1234 "
To Hull	" 37 "
Total	" 8343 "

A good deal of this was re-exported, as it could not compete with Colonial.

PRICES CURRENT.

Low brown, equal to No. 7 to 8 Dutch standard—very scarce	21s 0d to 22s 6d
Light brown, equal to No. 10 to 10½ Dutch standard	23s 6d to 24s 0d
Grey and yellow, equal to No. 12 Dutch standard	25s 0d to 25s 6d
Per cwt., cost, freight and insurance to cover average.	

In Russia the consumption has nearly doubled within a few years; but even now it is only two pounds per head.

Dr. ANGUS SMITH of Manchester kindly rendered his valuable aid during the progress of this article, and for which the Editor is indebted to him.

SULPHUR—*soufre*, French; *schwefel*, German—is one of the elements of modern chemists, and was a still more important one in the theory of the alchemists.

OCCURRENCE.—It is found in nature, both in a free state and in combination with metals, as sulphides and sulphates. In the free state it occurs in volcanic regions, large quantities being imported to this country from Sicily. The native sulphur occurs both amorphous and crystallized. In the latter state it usually occurs in right rhombic octohedra, although it does not assume this shape under all conditions; it crystallizes in many

The duty is now seven and a half groschen for one hundred pounds, and brings nearly three shillings per head.

AMOUNT OF RAW BEET-ROOT USED FOR THE PRODUCTION OF SUGAR, AND AMOUNT OF DUTY RECEIVED IN THE STATES OF THE ZOLLVEREIN.

Years.	Amount of beet-root used for sugar.	Produce of sugar in rix-dol.
	Cwt.	
1842 to 1847	4,322,712	232,991
1847 to 1853	13,998,570	1,156,744
1853 to 1856	19,832,679	3,966,596
1856 to 1857	27,551,207	5,312,856
1857 to 1858	28,915,133	5,783,023

CONSUMPTION OF BEET-ROOT SUGAR IN THE STATES OF THE ZOLLVEREIN.

Years.	Consumption of colonial sugar.	Consumption of beet sugar.	Total consumption of sugar.
	Zollverein cwt.	Zollverein cwt.	Zollverein cwt.
1844 to 1846 ..	1,278,421	264,283	1,542,704
1847 to 1849 ..	1,154,005	646,650	1,800,655
1850 to 1852 ..	739,958	1,219,718	1,959,676
1853 to 1855 ..	654,386	1,487,452	2,141,838

In 1856-57 there were two hundred and thirty-three manufacturers of beet-root sugar in the Zollverein. In 1839-40, four and four-fifths pounds per head was consumed; in 1853-55 there were six and a quarter pounds consumed.

The shipments of beet-root sugar, according to BARUCHSON and Company of Douai, to Great Britain, were little more in 1858-59 than half those of the preceding season, owing to the prices in England being at several periods below those of France. They consist as follows:—

forms, almost as varied as the methods of procuring the body in the crystallized state. Native sulphur is far from being pure, containing a considerable quantity of adhering soil and other matter, from which it is purified by different methods dependent on the purposes to which it is to be applied. Large quantities of sulphur exist in combination with metals as sulphides; of these may be mentioned the sulphides of copper, lead, iron, and zinc; these bodies, in fact, forming the ordinary ores or minerals of these metals, from which the sulphur has to be burnt off before the metal itself can be obtained. Sulphur occurs also in nature in saline combinations as sulphates of the alkalies and earths; for instance, the sulphate of soda and potassa, which are comparatively rare, and the sulphates of baryta and lime, which occur in immense quantities.

PROPERTIES.—Sulphur is a pale yellow, solid, very

brittle, becoming negatively electrical by heat or friction; it was at one time, in an earlier period of electrical history, used, when formed into globes and mounted as glass cylinders and plates are at the present day, as a source of electricity. Its specific gravity is variously stated, but most writers agree in considering it as 1.98—probably its density is dependent on the degree or stage of heat to which it has been carried while in a fused state. It is perfectly inodorous unless when rubbed, when a peculiar smell is developed. This was once supposed to arise from a hydrogen compound formed by friction; it is now ascribed rather to the production of ozone. Owing to its brittleness, as well as from conducting heat badly, it soon splits into innumerable cracks when held in the warm hand; by inclosing a stick of cast sulphur in the hand, and holding it close to the ear, this is easily detected, a continued series of very slight cracklings are heard similar to the cracklings of an electric machine when in work, only much fainter. Sulphur, though perfectly insoluble in water, is soluble in a variety of liquids, most of which are capable of dissolving a greater quantity of the body when hot than they are when cold, in consequence of which they, on cooling, deposit this excess in the shape of crystals. Oil of turpentine is capable of dissolving a considerable quantity. In fact, it has been proposed to take advantage of this property in the analysis of gunpowder; for by heating this body with turpentine in a warm state, having previously dissolved out the nitrate of potassa with water, we can dissolve out the sulphur, leaving the charcoal, which is not soluble in this menstruum, behind. Bisulphide of carbon will also dissolve a considerable quantity of sulphur, which can be again obtained in crystals by allowing the solvent to evaporate gradually. Fat oils are also capable of dissolving it. A compound called *oleum sulphuratum*, or balsam of sulphur, once figured in the Pharmacopoeia of the London College, though now omitted. This was formed by dissolving sulphur in olive oil, employing a tolerably high temperature to effect the combination. Ether, petroleum, and fused paraffine, may be mentioned as solvents of sulphur.

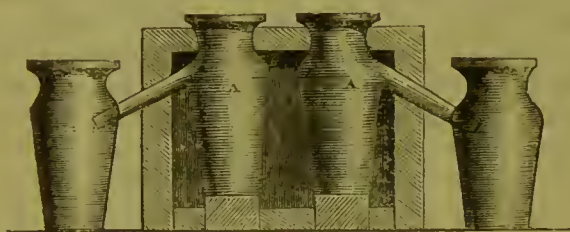
Pure sulphur exhibits some curious phenomena in connection with heat. Although perfectly solid at the ordinary temperature, it fuses at a heat little more than that of boiling water, and at a higher heat passes through various physical changes; and finally, on raising the temperature still higher, it volatilizes completely, without leaving anything behind. The following experiment is interesting, as displaying some of the peculiarities of this body:—Procure a small saucepan, and partly fill it with fragments of sulphur; place this over a gentle fire, having first put on the lid; after a while it will fuse. This takes place at a temperature of about 228°, forming a thin brownish-yellow transparent liquid. On heating still higher a very perceptible change takes place; the sulphur, instead of remaining in the very liquid state, becomes of a thick consistence, so much so that the vessel containing it may be completely inverted without fear of loss. This occurs at a temperature of between 428° and 482°. At a still higher degree the action is reversed, the melted sulphur becomes thinner and thinner until it reaches the boiling point,

when it begins to pass off as vapor. Other phenomena may be noticed by interrupting the experiment at various stages; for instance, if it be wished to obtain crystals of sulphur, it is only necessary to take the sulphur while in the first liquid stage, to pour this into a basin or other vessel with sloping sides, and there allow it to stand. In a few minutes after the top portion has solidified and formed a crust, break two holes through this crust at opposite sides of the vessel. If the basin be now inverted partially, the sulphur, which still remains in the liquid state in the interior, will run out of one hole while air rushes through the other. Let the vessel stand until cold, carefully detach the solidified mass from the containing vessel, and by means of a saw divide it into two halves. These will be found to be full of beautiful crystals of sulphur. It is possible that the first experiment may not be very successful, but a few trials will enable the operator to procure a mass of crystals, radiating into, and interlacing each other in every direction from the external crust. If the sulphur, immediately after passing, or perhaps better, while scarcely through the thick stage, be poured into water, it does not solidify and assume the ordinary yellow brittle appearance which it would do were it so treated while in the first liquid state; instead of doing so it remains in this plastic condition even when cold, bearing a stronger resemblance to caoutchouc than sulphur. In this state it is perfectly elastic, may be pulled out to a considerable length without breaking, and, in fact, does not in the remotest degree resemble sulphur. But for its color, it might be mistaken for wheat gluten, possessing the same soft elasticity as that body. It will remain in this state for some time, not resuming its ordinary aspect until after the lapse of some days.

PURIFICATION.—Sulphur occurs in commerce in several states of purity, the native sulphur being the most impure. In order that it may be more fit for the several uses to which it is applied, it is partially purified from the grosser extraneous matter, such as gravel, sand, *et cetera*. This is done, according to some authors, by throwing a quantity of the crude native sulphur into a suitable iron vessel or pan, and heating this pan until fusion takes place. The sulphur when fused, of course, occupies much less space than it did in the heap, so the operator keeps filling up the pan until it is full of the fused sulphur. A high heat is not advantageous. This may be inferred from what has been said before respecting the changes which take place during the fusion of sulphur at different temperatures. For the purpose of purification the lowest heat consistent with perfect fusion is the one to be employed. The liquid sulphur is thus in its thinnest state, easily allowing the heavy particles with which it was contaminated to fall to the bottom of the pan, while any light particles rise to the top, and are skimmed off. When some time has elapsed, and the operator considers that sufficient subsidence has taken place, he proceeds to remove the upper stratum of tolerably pure sulphur, running it into moulds, from which it is removed as solid blocks of sulphur. That the method is not perfect is easily ascertained by burning a piece of ordinary commercial sulphur in a porcelain capsule. A quantity of light dust will remain,

consisting to a large extent of sulphate of lime; yet, though the purification is not absolute, it produces an article pure enough to be employed for almost every purpose required in the arts. In order to procure an almost absolutely pure article, such as is necessary for medical and a variety of other purposes, distillation, or rather sublimation, must be had recourse to. Sulphur, as has been before stated, is perfectly volatile; a ready method therefore exists of separating it from all bodies which are not so. It is said that the following apparatus—Fig. 567—is employed to effect this. A A, are two earthenware or fire-clay jars,

Fig. 567.

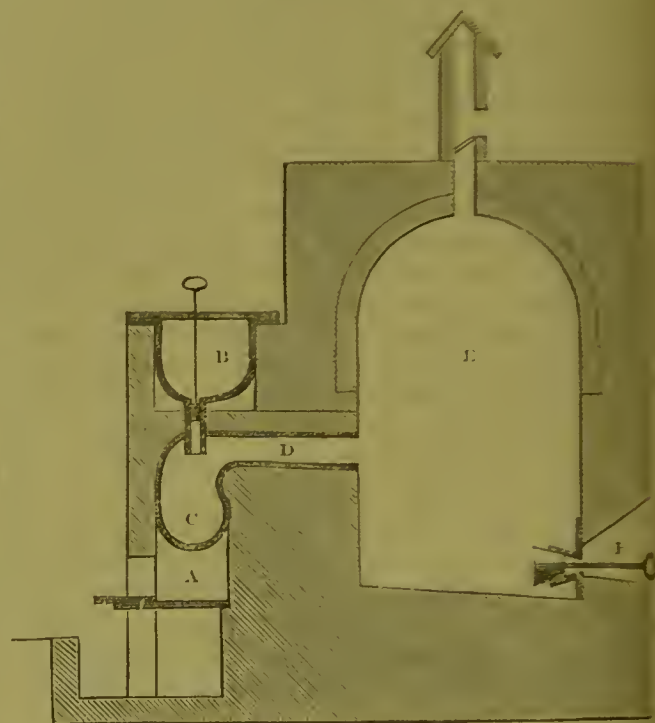


standing on a raised support of bricks. The mouths of these jars protrude slightly over the top of the furnace. This is for the purpose of readily enabling the operator to fill in the charge, and to remove the earthy residuum. A hollow tube or arm projects laterally and slightly downwards from each of the pots or retorts, which arm is thrust into another pot or vessel to receive the sublimed sulphur which condenses into it. When the subliming pot has received its charge, the lid is luted on and the furnace lighted. As they become heated, the various changes of fusion take place up to the last, when sublimation begins. The vapor then passes over into the condensing jar, and becomes solid. All the extraneous matter is left in the subliming pot, from whence it is removed prior to the introduction of another charge. This apparatus, *if actually employed*, could certainly furnish only a small quantity of sulphur. It is hardly possible to imagine a large gunpowder work using such an apparatus.

In 1815 a manufacturer named MICHEL, of Marseilles, devised an apparatus which, with some slight modification, is used up to the present day. The drawing—Fig. 568—represents it, and which, like the one previously described, contains a retort wherein the sulphur is converted into vapor, and a condensing chamber in which this is reconverted into solid sulphur. The apparatus, as in the drawing, consists, first, of a retort, C, beneath which is a furnace, A; this retort is filled with liquid sulphur from the reservoir, B, wherein the crude sulphur is melted by the waste heat of the furnace to facilitate its introduction to the retorts. When the retort has become sufficiently hot the sulphur begins to pass as vapor through the tube or opening, D, into the condensing chamber, E. This chamber is built entirely of brick, with a well-cemented brick floor; on its upper part a small chimney is erected; this chimney contains a sort of wooden valve or door, capable of opening outwards, to allow the expanded air to escape, and in case of explosion to allow the gases produced immediate exit. This apparatus when cold allows solid sulphur

to form at once in the shape of the ordinary commercial flowers of sulphur; the vapors immediately on coming into contact with the cold chamber are chilled and fall as a minutely divided solid. These flowers, as they

Fig. 568.

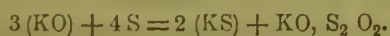


are called, are removed before the chamber gets hot, which is the case after a few days' working, the whole of the heat which the sulphur had taken up, in order to become vapor, being given out to the walls: they thus acquire so high a temperature as to fuse sulphur, therefore it can no longer become solid in contact with them, but condenses on their surface in a liquid form, and runs to the bottom, where it collects. When the operator is satisfied that sufficient has distilled over, he proceeds to remove it; this he does by means of the plug apparatus, figured at F, which is simply an iron plug with a tolerably long shank or handle, as is shown in the drawing; by pushing this plug inwards he opens the passage for the flow of the liquid sulphur, which runs into suitable moulds, to form the *stick or roll* sulphur of commerce. The residue is raked out of the retort, which is immediately charged again by removing the plug which closes the tube or passage between the vessel, B, and the retort. An apparatus better calculated for the purpose than the above, is figured in PAYEN'S *Precis de Chemie*, in which two retorts are attached to one condensing chamber; these retorts are cylindrical, and resemble to a certain extent ordinary gas retorts. A portion of the door which closes the outer end of the retort is movable, to enable the operator to rake out the debris left after distillation, the other end of the retort rises like a swan's neck before opening into the condensing chamber. Over these openings or orifices within the chamber hangs a damper or register in such a manner that it can, from the outside, be placed over them, thus cutting off all communication between the retort and the chamber.

A fusing vessel heated by the waste heat is attached, as in the drawing just given. This description of apparatus has the advantage, that by its means the operation can be rendered continuous. For instance, let one retort be called A, the other B; suppose retort, A, charged at a certain hour, and retort, B, charged some two hours later, it is certain that were they charged with an equal weight of raw material, the retort, A, would be ready for recharging two hours before retort, B. Supposing this to be the case, the damper or sliding plate is allowed to fall over the opening of retort, A, thus closing the passage between it and the condenser, and preventing the rushing back of any sulphur vapor. The cover is removed from the front opening, the impure residue raked out, after which it is again closed, the entrance into the condensing chamber is again opened, a charge of sulphur is run in from the fusing vessel, and the distillation again commences. During the whole of these operations retort, B, has been uninterruptedly at work; but eventually the same operations have to be performed in connection with it as have been detailed with respect to retort, A. Thus between the two a constant stream of sulphur vapor is being perpetually driven into the condensing chamber, the work going on almost without interruption, as the retorts never want charging simultaneously.

Sulphur thus produced is almost pure. It is true that the sublimed sulphur in powder—that is, the flowers of sulphur—contains a small quantity of sulphurous acid, which for some purposes it is necessary to remove by washing with water, but this is pretty nearly the only body it is contaminated with; the roll sulphur is free from sulphurous acid.

Sulphur occurs in commerce in another form intended expressly for medical use. When in this shape it is called *milk of sulphur*, and consists of sulphur in a very minute state of division. It is obtained in this state by dissolving ordinary roll sulphur bruised, or the flowers, in any caustic alkali, either soda, potassa, or lime; the latter used as being cheaper, and furnishing, as will be explained hereafter, a convenient adulterant. Sulphur does not dissolve in the alkaline solutions in the same manner that it does in turpentine, or any of the before-mentioned solvents. When boiled with an alkali a series of chemical compounds or salts are formed; in spiritous liquids it is a case of simple solution, exactly the same as dissolving sugar or salt in water, whereas in the other, a series of definite chemical phenomena takes place. If to a boiling solution of caustic potassa there is added as much sulphur as it will possibly take up, a liquid will be obtained containing sulphide of potassium, and hyposulphite of potassa, according to the following equation:—



In the first instance, while there is an excess of alkali, and little sulphur taken up, there is formed only sulphide of the alkaline metal and sulphite of the alkali; but this sulphite, by being boiled with an excess of sulphur, takes up another equivalent of it, being itself converted into hyposulphite. The clear liquid obtained in this way must be filtered or poured off the sediment, and excess of sulphur, and either sulphuric or hydrochloric

acid added until the liquid reddens litmus paper, when the dissolved sulphur is again precipitated in an exceedingly fine state of division. This is washed, drained, and dried at a gentle heat. It remains to examine the reaction by which the sulphur is again obtained. To do this, it will be well first to notice what the effect would be of adding acid to separate solutions of the two salts which form the mixture. If a solution of sulphide of potassium be taken, and an acid be added, a copious evolution of sulphide of hydrogen ensues, and there is obtained very little, if any, precipitated sulphur. Again, if acid is poured into a solution of hyposulphite of potassa, only a little sulphur will be separated. Hyposulphurous acid consists of sulphurous acid plus one equivalent of sulphur. Now hyposulphurous acid can only exist in combination; when set free it is instantly decomposed into sulphurous acid and sulphur— $\text{S}_2\text{O}_2 = \text{SO}_2 + \text{S}$. This is the case on adding an acid to hyposulphites. In the first place, the alkali is detached from its combination, and this hyposulphurous acid being set free gradually resolves itself into sulphurous acid and sulphur.

It is well known that when sulphide of hydrogen and sulphurous acid are brought into contact with each other a decomposition ensues, water and sulphur being the result, as shown in the following equation:—



Thus is explained the reproduction of the whole of the sulphur employed. Hyposulphurous acid and hydrosulphuric acid, or sulphide of hydrogen, are set free in the first instance; the hyposulphurous acid splits into sulphur and sulphurous acid, the latter immediately reacts upon the sulphide of hydrogen, producing together sulphur and water. This reaction is not very complete, although it is nearly so—the more correct reaction is given under *Pentathionic Acid*. In ROYLE'S *Materia Medica* it is recommended, in order to obtain milk of sulphur, to boil one part of sublimed sulphur with two parts of slaked lime and sufficient water, and to add hydrochloric acid to the clear liquid obtained.

Lime is almost invariably used by the manufacturers as a solvent, but they are guilty of substituting sulphuric acid for hydrochloric as a precipitant. By so doing, instead of forming the soluble chloride of calcium, which is easily removed by washing, they form the very insoluble sulphate of lime which, mixed with the sulphur, forms the article commonly sold by druggists as milk of sulphur, and thus what should be pure sulphur is contaminated by this worse than useless sulphate of lime, often to the extent of more than fifty per cent. In one sample obtained from a druggist, and which was stated to be pure, fifty-six per cent. of sulphate of lime was found. It is useless to argue that such a sophistication is harmless; for, although not positively poisonous, the introduction into the stomach and bowels of a quantity of this insoluble matter cannot but be productive of harm. Sulphur is used in medicine as a mild purgative, and in some skin diseases. The stores of sulphur which this country possesses, in one form or another, has not been overlooked by practical scientific men.

EXTRACTION OF SULPHUR FROM ITS ORES.—The immense quantities of sulphur stored up in the shape of sulphate of lime and baryta, as well as the sulphides of iron, zinc, lead, and copper, is almost beyond calculation. There is good reason to suppose that at some future time the sulphur combined with these metals, and which at the present time is separated from them only to be thrown into the air, will be recovered in a tangible solid form, at a price low enough to compete with foreign sulphur. The attempts to do this already have been numerous. In many parts of the country iron pyrites is plentiful, and this mineral appears to have been a favorite material with inventors. It is a mixture of bisulphide and protosulphide of iron. The second equivalent of sulphur of the bisulphide is held rather loosely, so much so that a red heat, continued for some time, will drive it off, leaving one equivalent of iron combined with one of sulphur, forming the protosulphide. Here, it would appear, a process for obtaining sulphur readily is at hand; but if it be considered that the sulphur ores of this country rarely contain more than thirty per cent. of sulphur, and that, at the most, but two-thirds of this exist as bisulphide, and that only half of this latter quantity can be expelled by heating with exclusion of the air, it will at once be apparent that the process could never be rendered remunerative. Such a method is, however, pursued in some parts of the Continent, where sulphur ores are found of a much richer kind, and in which there is also a greater proportion of bisulphide, but not exactly by the same method that sulphur is purified. The process appears to be one of slow distillation of one part of the sulphur, at the sacrifice, by combustion, of the other. It is stated—KNAPP—that not more than one-fourth of the sulphur actually contained in the pyrites is obtained. This process has formed the base for several improvements. It would appear that inventors are quite aware of the benefits that would result from the discovery of a process whereby sulphur could be separated from the pyrites on the spot, even if only the saving the expense of carriage, if nothing else, of the vast quantity of iron. The following process was invented by Mr. LEE. He first converts the sulphur in the pyrites, or other mineral, into sulphurous acid, and then proceeds to recover the sulphur from this by passing it through a quantity of coke heated to bright redness. The oxygen of the sulphurous acid combines with the incandescant carbon, forming carbonic oxide, *et cetera*, while the sulphur is left in a free state, and in vapor. It passes on to a suitable condenser, in which the bulk of it is recovered in a melted shape; that which escapes melting is received into a vaulted chamber similar to the one employed in the refining of sulphur by sublimation, and in these obtained solid in the form of flowers of sulphur.

This process, or rather the apparatus, appears to be of a very complicated character. Mr. SPENCE of Manchester, in a process patented by him a few years ago, has materially simplified it, although he works on precisely the same principle. Mr. SPENCE's apparatus consists simply of an ordinary pyrites burner, such as is used in the manufacture of sulphuric

acid, to which is attached a number of condensing vaults. He charges his burner with alternate layers of charcoal and the pyrites under treatment; having first heated the brickwork of the burner up to the proper pitch. When at work, the action is very simple—the pyrites burns with production of sulphurous acid; each atom of this gas has to traverse a bed of layer of red-hot charcoal. Now, as just before stated, carbon having a greater affinity for oxygen than sulphur has, forces this sulphurous acid to yield up the oxygen, thus setting the sulphur free. The sulphur passes on with the current of gases, and is deposited in a state of powder in the condensing chambers. This plan appears to be more feasible, and better capable of working on a large scale than the one preceding.

While speaking of precipitated sulphur, it was shown how it was possible for sulphide of hydrogen and sulphurous acid gases to react upon each other, the eventual products being water and sulphur. This reaction has been taken advantage of in a process patented by Mr. DUCLOS of Swansea. He proposes to conduct in a leaden chamber, such as is used in the production of sulphuric acid, a mixture of two volumes of sulphide of hydrogen and one volume of sulphurous acid, a quantity of steam being at the same time admitted into the chamber. This, at first sight, appears to be very workable. It is easy to see that the two gases could be regulated to each other, and a constant action go on: the sulphur in a fine state of division would be deposited on the floor of the chamber, while the excess of atmospheric air, *et cetera*, would go out through proper openings at the end of it. But it unfortunately happens that only about one-half of the sulphur actually contained in the two gases is obtained. When these two gases are brought together, water being present, the results actually are water, sulphur, and pentathionic acid—an acid of sulphur with the formula S_5O_8 . Its production may be explained as follows—

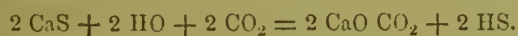


that is to say, that five equivalents of sulphurous acid and five equivalents of sulphide of hydrogen produce, by their mutual reaction, five equivalents of water, five equivalents of sulphur, which are deposited, and one equivalent of pentathionic acid. By calculation it is thus found that by this only one-half of the sulphur would be obtained in the solid state, for in the sulphurous acid there are five equivalents of sulphur, and five more in the sulphide of hydrogen; and for these ten equivalents of sulphur one recovers only five, the rest going to form the pentathionic acid, a body for which no use in the arts has yet been found. Thus, instead of burning the pyrites, or other minerals, and endeavoring to separate the sulphur from the sulphurous acid produced, it would be more economical to convert it into sulphuric acid at once.

Mr. GOSSAGE surmounted the pentathionic acid difficulty, by causing the reaction to take place at a high temperature. His process is peculiarly applicable to the reproduction of the sulphur contained in the lime compound or alkali waste thrown away by the soda manufacturers. As is well known, the whole of the sulphur used in the manufacture of the alkali finds

its way into the vat waste. Mr. GOSSAGE proceeds to decompose this vat waste by means of carbonic acid. The action of this acid causes sulphide of hydrogen to be evolved. A portion of this sulphide of hydrogen is converted by burning into sulphurous acid, which sulphurous acid is made to react, at a high temperature, on a fresh portion of sulphide of hydrogen, when water and sulphur are produced. His apparatus consists of four distinct portions—the first for the production of the requisite carbonic acid; the second for the decomposition of the alkali waste; the third is for the decomposition of the sulphide of hydrogen; and the fourth for the collection of the sulphur produced. The apparatus for the production of the carbonic acid is an ordinary lime-kiln, with some additions to render it more fit for the special purpose to which it is to be applied. It is fed with a mixture of common coke and limestone, air being admitted for the purpose of combustion in the usual manner. The apparatus is of the continuous kind. It is fed constantly at short intervals with the above materials, the quicklime produced being removed from the bottom of the kiln at stated periods. The action of this kiln is simply the decomposition of the limestone, the carbonic acid evolved, together with that furnished by the combustion of the coke, being carried to where it is needed in the next stage for the decomposition of the vat waste.

The composition of this compound may be considered definitely settled. It seems to be tacitly allowed with DUMAS that its composition is $2 \text{ CaS} + \text{CaO}$, or two equivalents of sulphide of calcium, united to one of lime; but the research of Mr. J. W. KYNASTON lately in the Editor's laboratory, has indubitably proved it to be simply a protosulphide of calcium with carbonate of lime. This substance, the composition and properties of which have been fully discussed under the article SODIUM, though insoluble in water, is capable of being decomposed by carbonic acid, especially when in a loose porous state; one equivalent of the lime compound, and three atoms of carbonic acid producing three atoms of carbonate of lime, and two of sulphide hydrogen, as follows:—



The apparatus employed, or proposed to be employed in the decomposition of this compound by Mr. GOSSAGE, consists of two large chambers, or rather large columns, filled with numerous perforated floorings or stages on which the alkali waste is placed; these chambers or columns are placed side by side, and so connected together, that the carbonic acid which is admitted at the bottom of one column, emerges at the top, and is conducted by a proper passage to the bottom of the adjoining column, up which it passes, as in the previous case. The material to be operated upon is laid on the perforated floors, in a loose open manner, to facilitate the passage of the carbonic acid; this ascending from the bottom of the column, penetrates through each of these separate masses, decomposing each particle with which it comes in contact. This course it pursues until it reaches the terminal point of this portion of the apparatus, at which time the carbonic acid is supposed to have been completely absorbed, and replaced by the

liberated sulphide of hydrogen which has now to be decomposed. In order to this effect, the inventor has constructed a furnace of a rather peculiar character. This furnace has a closed ash-pit, or an ash-pit whose inlet can be closed or not, at pleasure, by means of a damper or register; the flue or passage for the gases leading from the waste decomposer is divided into two at this point, one part of the sulphide of hydrogen is drawn into this ash-pit, and so through the bars and fuel of the furnace, while the other portion is admitted immediately above the burning fuel; by this means a quantity of sulphurous acid is produced, which, in coming in contact with a fresh portion of sulphide of hydrogen at this high temperature, decomposes it, forming, as shown before, sulphur and water. This sulphur, of course, is in the state of vapor, mixed or diluted with a variety of other gases; it now remains to separate this valuable ingredient from the mass of inert and useless gases which accompany it. For this purpose an apparatus similar to the one last described is employed. This column is built of bricks or other suitable material, and is filled with coke; a cistern of water is placed on the top, by means of which, with the assistance of an apparatus for the spreading of the water in the form of rain over the whole area of the column, the coke is kept drenched with a stream of water. The vapors issuing from the furnace, consisting, as before stated, of sulphur vapor, mixed with other gases, is forced or drawn in at the bottom of this column, when, meeting with the cold wet coke, their temperature is almost instantly brought below the melting-point of sulphur, and this body is deposited in the solid state in the form of an impalpably fine powder, which mixes with the stream of water, and is finally carried out with the stream, forming with it a milky liquid, which falls into a proper cistern or reservoir, from which the sulphur is separated by deposition; from thence it is removed, and fused into a coherent mass, to fit it for the purposes of commerce. Between each of the different portions of the apparatus just described, the inventor places an ordinary draught or blower-fan, which rapidly removes the gaseous products from one portion, forcing them into the next. The various columns, *et cetera*, are of such dimensions as to insure a sufficiently quick passage for the products.

In theory this would appear to be perfection, inasmuch as we have here the recovery of the sulphur, which is the main object; and also the recovery of the lime, this body being left as carbonate after decomposition. As most alkali manufacturers are also manufacturers of bleaching powder, or chloroxide of calcium, this process offers an unfailing supply of lime; or if the recovered carbonate of lime just spoken of should not be found to answer for the soda decomposition a second time, that produced in the kiln could be used in the black-ash furnaces, instead of the limestone usually employed. It thus offers a considerable advantage if it should turn out to be as practically valuable as it is theoretically interesting.

Messrs. M'DOUGALL and RAWSON, in a patent, dated May 21, 1849, claim a process for the reproduction of sulphur from sulphide of hydrogen, from whatever source obtained. This they effect by passing it through

a pipe, heated to a red-heat, wherein the gas is split up into its constituent elements, sulphur and hydrogen; the sulphur is collected in any convenient manner. This process does not appear eminently practical, if the experiments of CORENWINDER be correct. He states that by passing sulphur vapor and hydrogen over or through porous bodies, kept at a red-heat, he obtained sulphide of hydrogen, exactly the reverse of this process. At any rate in a laboratory M'DOUGALL'S operation answers perfectly.

Messrs. DYAR and CHISHOLME secured a patent in 1839, for the recovery or reproduction of sulphur from sulphurous acid. It consisted in submitting the gas while at a red-heat to the action of hydrogen, which latter seized upon the oxygen, forming water and liberating sulphur. Two furnaces of proper construction were erected, side by side, one adapted to the combustion of pyrites, the other constructed in such a manner that it afforded a stream of hydrogen, mixed with carbonic oxide, obtained by passing a current of steam through or among incandescent coke. The gases were brought together at a point of junction kept sufficiently hot by the combustion of the materials themselves. At this point the decomposition took place, the sulphur vapor passing on to a proper condensing apparatus.

Amongst a most numerous array of methods for procuring sulphur, or for separating it from natural combinations, perhaps one of the most theoretically ingenious is that mentioned by PARNELL as being devised by M. THAULOW. It is for producing sulphur from the natural sulphate of lime. He proposes to reduce this to the state of sulphide of calcium, which salt he then decomposes by means of carbonic acid, obtaining by this means sulphide of hydrogen and carbonate of lime. He effects the deoxidization of the sulphate of lime, or its reduction to sulphide of calcium by mixing it, in fine powder, with coal-dust, exposing this mixture to a red heat for a sufficient length of time in a retort of clay or iron; the carbon unites with the oxygen of the sulphuric acid and lime, and becomes carbonic acid, which he reserves, or immediately uses for the decomposition of a previous charge. Carbonic acid, as stated while describing Mr. GOSSAGE'S process, is able to decompose sulphide of calcium, driving off sulphide of hydrogen. Thus M. THAULOW proposes to burn sulphide of hydrogen in lieu of sulphur for the production of sulphuric acid. There are reasons for supposing that this process can never be successfully carried out. In the first place, as PARNELL observes, if the exact quantity of carbon only necessary to combine with all the oxygen present, is added, the reduction would be extended over a great length of time, and would probably never be complete; and again, were an excess of carbon to be employed, so as to hasten the decomposition, carbonic acid would not be obtained, for carbonic acid passed over red-hot carbon would part with half its oxygen, becoming carbonic oxide—CO—a gas which could not possibly be substituted for the carbonic acid in this case. By a little addition the process can be made theoretically possible; still, the probabilities are that it will never be practically worked, unless sulphur should rise in price much higher than it is likely to do.

As an instance of the manner in which old and useless, or exploded inventions again arise, one may mention the re-invention or revival of this very process by OTTO KÖNSELL, who patented it for the kingdom of Hanover in 1856. The process, as detailed by the inventor, is precisely the same in every detail as that of M. THAULOW—not the main principal only, but in every minute particular it is a perfect copy.

In 1857 Mr. GOSSAGE invented, and secured by patent—dated September 12th in that year—another process for obtaining the sulphur from the sulphide of calcium or alkali waste. In the place of hydrochloric or carbonic acid, as in his method of decomposition before mentioned, he liberates the sulphur in the form of sulphide of hydrogen, by acting upon the waste with steam at a high temperature. The following equation represents the change that ensues—



The sulphide of hydrogen so obtained he applies instead of sulphur, in the production of sulphuric acid by burning with atmospheric air, so as to form sulphurous acid gas; or he obtains the sulphur itself from the sulphide of hydrogen by causing sulphurous acid to act upon it, when mutual decomposition takes place.

When carbonic oxide gas is passed over the sulphates of the alkalies or alkaline earths in a state of ignition, the salts are reduced to sulphides with the simultaneous conversion of the carbonic oxide to carbonic acid, thus—



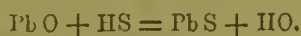
Now, as Mr. GOSSAGE has shown, if steam at a high temperature be caused to act upon the sulphides of the alkaline earths, sulphide of hydrogen is liberated. If, therefore, a mixture of steam and carbonic oxide gas be passed over the ignited alkaline, or earthy sulphates, the sulphur of the sulphate will be obtained as sulphide of hydrogen, and may afterwards be obtained in the free state. This method has been lately proposed by M. JACQUEMIN, for the production of sulphur from sulphate of lime, and also for obtaining, at the same time, soda in the caustic condition from sulphate of soda.

The author appears to think that by means of this process he will revolutionize the soda manufacture, as he anticipates the recovery of the whole of the sulphur in an available form without the production of any waste whatever. Even if this process would answer on a small scale, its success on a larger one is very doubtful. Were its success an absolute and undoubted fact, and the reaction clean and exact, it would be capable of considerable extension. The sulphur from sulphate of lime might be recovered in like manner. It would only be necessary to mix it in the manner M. THAULOW proposes to do with small coal, or other carbonaceous or reducing matter; heat to bright redness in a closed retort for some hours, until it was reduced to the state of sulphide of calcium; then to pass steam over and drive off the sulphur as sulphide of hydrogen, while lime would remain behind as

quicklime. This process, which is tacitly indicated by the author, should be much superior to that of M. THAULOW just mentioned; but it would appear that a like fate has awaited both processes; in fact, that they are each impracticable on a large scale, or, what is the same thing, they would not pay at present.

These are not the only methods which have been proposed for the recovery of sulphur from its various combinations; but they serve to show, to a certain extent, the industry of the various inventors who have turned their attention to the subject; and though success has not followed to the extent no doubt expected by the sanguine chemist, there is no reason for despair. It is still to be hoped that some one, more successful than his predecessors, may yet, in some fortunate moment, hit, either upon a yet latent reaction, or by some perhaps trifling variation of an already known mode of procedure, bring forward a simple and easily-worked process, that shall be all that could be desired, producing sulphur at a price sufficiently low to compete successfully with the imported article. Sulphur, in a state of combination, exists in this country in almost inexhaustible quantity. To separate this, and to produce it in a state of comparative purity, is what is wanted. When this is done, English manufacturers will be in a state of great independence. It scarcely need be added that by such a discovery the fortunate individual would be more than repaid for a life's industry.

COMBINATIONS OF SULPHUR.—Sulphur enters into many combinations, both simple and complex; it combines, with a few exceptions, with all the metals, forming with them proper insoluble compounds. The sulphides of the alkaline and earthy metals are soluble in water. Some sulphides are decomposed by acids, while others again are insoluble in these liquids. Of these peculiarities chemists avail themselves largely in analysis; for, by this property of forming insoluble compounds with sulphur, they are enabled to separate into classes several groups of metals, from which again, by a series of subdividings and subclassings, they can separate individually each element. The larger groupings are made chiefly through the instrumentality of sulphide of hydrogen. This gas, when passed through a solution of metallic oxides, in many cases throws down the metal as a sulphide, the gas being decomposed. As an example: if a current of sulphide of hydrogen be passed through a solution of a salt of lead, the following reaction takes place—

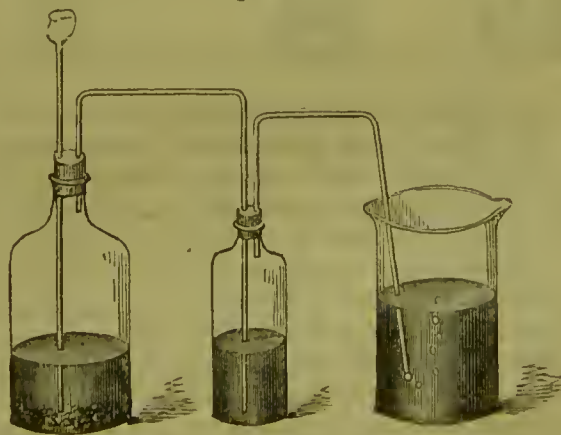


Sulphide of lead and water are the products of this decomposition. The following metals are thrown down as sulphides by sulphide of hydrogen from an acid solution—gold, platinum, mercury, silver, lead, bismuth, and copper, black; antimony, orange; arsenic, tin, and cadmium, yellow. The following metals are converted into sulphides when sulphide of hydrogen is passed through their alkaline solutions, or a slightly alkaline solution, in which their hydrated oxides are suspended—nickel, iron, and cobalt, yellow; tin, black; manganese, flesh-colored; zinc, white. Sulphur enters into the vegetal kingdom; it is found in more or less

quantity in many plants, chiefly in connection with nitrogen, with which it would appear to act in consort, at least in the organic world. In the animal kingdom it occurs pretty extensively also, and there too it is principally found in nitrogen compounds. Animal and vegetal products of the albumen and fibrin class contain it as an essential element, while its existence in the form of salt, as sulphate, *et cetera*, is still more diffused. It combines, as will be presently shown, with several proportions of oxygen, and with hydrogen in at least two proportions—the sulphide of hydrogen spoken of so repeatedly in this article when treating of the recovery of sulphur, and another body containing much more sulphur, its formula being given as HS_2 . This body is produced, appearing in the form of oily drops, which subside when a solution of pentasulphide of potassium is poured into dilute hydrochloric acid; it is very unstable; the greatest care and precaution cannot preserve it longer than a few weeks, even though it be sealed hermetically in a glass tube; it simply forms a link of the chain of combinations which sulphur is capable of forming.

The simpler combination with hydrogen is a well known body; it is the result of many decompositions, natural and otherwise; it is permanently gaseous, possessing a most nauseous odor, easily recognized as being the characteristic of several mineral springs, such as those of Harrowgate, *et cetera*. It is a product of the decomposition of many organic bodies, is evolved by putrid bodies, and is the cause of the smell of rotten eggs, the albumen of which, as before stated, contains a quantity of sulphur, is undergoing decay, and gives off its sulphur, or a part of it, as sulphide of hydrogen. This gas is prepared by adding an acid to any soluble sulphide, such as those of the alkalis, or of the alkaline earths. The most convenient, and consequently the most general method, consists in adding dilute sulphuric acid to sulphide of iron, placed in a bottle, closed with a cork, perforated with two holes, one for the passage of a tube funnel, through which sulphuric acid can be poured; while through the other is passed a tube for the exit of the gas—Fig. 569. If a slow

Fig. 569.



and constant stream of the gas is required, large lumps of the sulphide should be employed; but if, on the contrary, a rapid stream is needed, smaller lumps should be used. When the sulphide is introduced, the cork should be put in its place, and the requisite

quantity of dilute acid poured down the funnel; if the sulphide be good, a stream of gas bubbles will immediately begin to rise, and passing through the exit tube, can be directed through any solution, or to any required point. The decomposition which produces this gas from these materials is very simple—

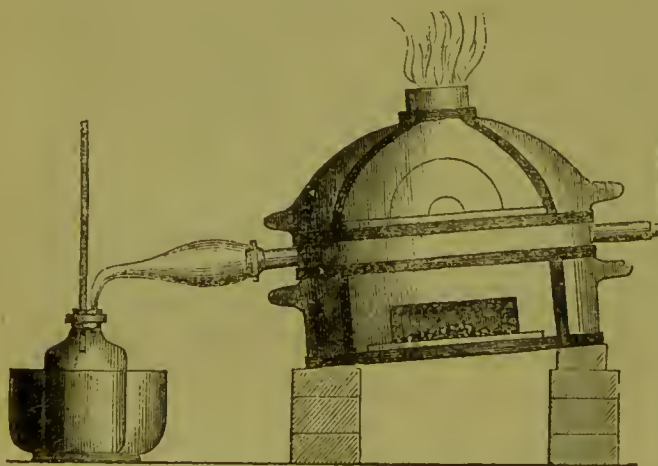


that is, one equivalent of sulphide of iron, one of sulphuric acid, and one of water, produce one equivalent of sulphide hydrogen, and one of protosulphate of iron.

The combination of sulphur with nitrogen alone is of scarcely any importance, and need not be dwelt upon.

Sulphur and Carbon.—Sulphur forms several combinations with carbon; the one most marked and of the greatest importance, inasmuch as it is used in the arts, is the bisulphide of carbon or sulphocarbonic acid— CS_2 . It is formed by passing the vapor of sulphur over or through red-hot charcoal. This is effected by filling an iron or porcelain tube placed across a furnace—Fig. 570—with fragments of charcoal. One end of this tube is connected with a condensing apparatus—LIEBIG's tube will do—plentifully supplied with cold water. The other end of this tube must be capable of being closed tightly with a cork. When the tube is sufficiently hot the cork is removed, and small

Fig. 570.



pieces of sulphur are pushed through near to the charcoal. The orifice being again closed, the sulphur is converted into vapor, and in passing through the *interstices* of the *incandescent* carbon, combines with a portion, forming the body in question, which, passing on to the condensing apparatus, collects as a liquid. After sufficient time has elapsed a fresh portion of sulphur must be introduced, the operation being continued in this manner until sufficient has been prepared. This product is by no means pure, containing more or less sulphur which has escaped combination, and from which it must be freed by distillation in a glass retort placed in a water bath.

Bisulphide of carbon has a density of 1.272. It is, as obtained above, a transparent, colorless liquid, of a strong disagreeable odor. This odor is due to a foreign

body, the true smell being of a vinous or ethereal character. A considerable portion of this smell may be removed by shaking it up in a bottle with a quantity of strong sulphuric acid and bichromate of potash. Bisulphide of carbon is a very volatile body, its boiling point being 110° . It rapidly evaporates, almost equalling sulphuric ether in this respect, diffusing its odor through the apartment. It is a very effective solvent of fatty matter. Grease stains may be removed by it from paper or woven fabrics. It is only necessary to place a piece of blotting paper below the stain, and drop the bisulphide of carbon on it; it dissolves the grease, and the blotting paper receives the solution. When brushed the fabric must be exposed to the air, when the odor rapidly and perfectly disappears. Bisulphide of carbon is also a solvent of phosphorus; when a little bisulphide of carbon is warmed in a test tube and a piece of phosphorus dropped in it, it rapidly dissolves. This is a case of true solution. The phosphorus is again deposited unaltered on the evaporation of the solvent. It has been proposed to employ this solution in warfare. Should a wooden building or a ship's sails. The solvent evaporates, leaving a thin layer of phosphorus, or, in the case of a ship's sails, leaving every thread or fibre covered with a coating of phosphorus. This quickly begins to oxidize, and finally takes fire, which fire will communicate to the surrounding parts. The experiment may be performed on a small scale by wrapping a little tow round the end of a wire, and dipping this into the phosphoric solution, when, on taking it out and waving it about, the bisulphide of carbon almost instantly evaporates, and in a few seconds the tow takes fire, the phosphorus having ignited first.

Sulphur and Chlorine.—Sulphur also combines in a variety of proportions with other bodies, as well as those named. It forms combinations with phosphorus, boron, iodine, bromine, fluorine, and chlorine. One of its combinations with the latter body is used in the manufacture of caoutchouc; it is prepared by passing chlorine gas through melted sulphur, forming the dichloride of sulphur, which is found to contain also sulphur in solution. From this it must be freed by distillation, at a low temperature, and, if necessary, the rectification repeated until its boiling point is stationary at 228.2° . This chloride of sulphur has some curious properties; by means of it, a species of artificial india-rubber may be produced. To procure this body take a quantity of vegetal oil, say linseed or rape, and mix it with one-tenth its bulk of chloride of sulphur, and slightly warm the mixture; a strong reaction takes place. Hydrochloric acid is disengaged, and a mass remains, which, when washed with water, becomes white, and is as elastic as genuine caoutchouc, with precisely the same appearance. This curious body resists the action of boiling alkalis; ammonia and concentrated acids are without action on it, and it resists the solvent powers of alcohol, ether, sulphide of carbon, and oils.

Compounds of Sulphur and Oxygen.—Sulphur appears to have a great affinity for oxygen, with which it combines in many proportions, forming a series of

compounds, all of which are acids. The following are known to exist at present :—

Hyposulphurous acid,.....	$S_2 O_2$
Pentathionic acid,.....	$S_5 O_5$
Tetrathionic acid,.....	$S_4 O_5$
Trithionic acid,.....	$S_3 O_5$
Sulphurous acid,.....	$S O_2$
Hyposulphuric acid,.....	$S_2 O_5$
Sulphuric acid,.....	$S O_3$

Of this series two members have been already noticed—hyposulphurous acid and pentathionic acid. Hyposulphurous acid cannot be obtained in the free state, as already mentioned. When set free it splits up gradually into sulphur and sulphurous acid. It is commonly met with in the form of hyposulphite of soda, a compound employed to a considerable extent by photographers, it being a solvent of certain silver salts, which are insoluble in water, such as the chloride, iodide, and bromide. Hyposulphite of soda will also dissolve sulphate of lead, and in analysis affords a ready means of separating this salt from sulphate of baryta.

Hyposulphurous acid is comparatively stable when combined with a base. The hyposulphites of the alkalis and of the alkaline earths are those most frequently occurring. They are prepared in a variety of ways, the most common methods being either by exposing an alkaline or earthy sulphide to the air, when it absorbs oxygen, forming a quantity of hyposulphites and other salts; or by boiling a sulphite of the base with sulphur. The reaction in the latter case is very simple. Take the sulphite of soda for instance. This has the formula NaO, SO_2 . Add to this one equivalent of sulphur— $NaO, SO_2 + S$; and hyposulphite of soda— $NaO, S_2 O_2$ —is produced.

The following method appears to be a favorite one for preparing the hyposulphite of soda in small quantities :—One pound of pure crystallized carbonate of soda, is dried as perfectly as possible. When powdered, this is mixed with five ounces of pure sulphur, the mixture heated in a glass or porcelain basin to the melting point of sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part into contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water, and boiled with sulphur for some time, and the liquid evaporated to the crystallizing point. Very fine and pure crystals are obtained in this manner. If the heat be too strong, part of the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is requisite. Hyposulphite of soda can easily be obtained by passing a current of sulphurous acid through a solution of sulphide of sodium, boiling, filtering, and evaporating to the crystallizing point.

The earthy hyposulphites, as above stated, are formed by exposing their sulphides to the air; for instance, in a solution of sulphide of calcium exposed for some time in this manner, a considerable quantity of hyposulphites form by double decomposition. The hyposulphite of soda or potassa may be formed by adding to a solution of the sulphide of calcium a solution of the carbonate of these alkalis.

Hypsulphite of soda is used to a small extent in

analysis as a reducing agent, also as a means of separating iron and alumina, dependent on the fact that hyposulphite of alumina is not stable at much above the ordinary temperature. For instance, suppose iron and alumina are both contained in a solution; to this solution is added as much hyposulphite of soda as will convert these bases into hyposulphites; this is done while cold. The solution is now heated to boiling. Hyposulphite of alumina decomposes at this temperature into sulphur, sulphurous acid, and alumina, while the iron salt being more stable remains intact. The whole is now thrown on to a filter; when the iron salt passes through, while the alumina remains on the filter; and it is washed, dried, and ignited. The iron is separated from the filtrate in the usual manner.

This reaction is used, also, to a very small extent in calico-printing. A hyposulphite of alumina is formed in the cold by adding a solution of chloride of aluminium to a solution of hyposulphite of soda. The result is a solution of chloride of sodium and hyposulphite of alumina. This is thickened in the regular manner, and printed on the fabric. The piece is then exposed to a temperature of 212° by means of steam, when the salt is decomposed, alumina being deposited on or in the cloth. This alumina so deposited dyes up with madder precisely like the alumina precipitated in the ordinary manner from the acetate.

This method does not offer any advantage over that usually followed, except in certain cases, where it is a convenient course, on account of the ordinary method being inadmissible.

The rest of these sulphur and oxygen compounds, with the exception of sulphurous and sulphuric acid, are at present useless in the arts, but are valuable in a scientific point of view.

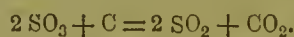
Sulphurous acid is composed of one equivalent of sulphur and two equivalents of oxygen. It is the irritating vapor or gas given off by burning sulphur. It may be prepared in a variety of ways, according to the purpose for which it is required. Two general principles may be followed, either the addition of a sufficient quantity of oxygen to sulphur, or the abstraction of oxygen from sulphuric acid.

When sulphur, as just stated, is made to burn in oxygen gas or common air, sulphurous acid is obtained. If it is desired to pass a stream of this gas through any liquid intended to absorb it, the sulphur must be burned in a close vessel or apparatus, which has a strong aspirator attached. The WOULD's hottle, or other vessel, must be placed between the vessel containing the sulphur and the aspirator, or, supposing this to be inconvenient, the sulphur may be mixed with some body containing oxygen loosely combined, and this mixture heated. A body possessing these requisite qualifications is found in peroxide of manganese. To obtain a stream

Fig. 571.



of sulphurous acid, it is recommended to make an intimate mixture of one part powdered sulphur, and seven or eight parts of black oxide of manganese. This mixture is placed in an iron retort, which is set on the fire. There is given off sulphurous acid, oxygen, and sulphur vapor, the matter in the retort being probably sulphide and sesquioxide of manganese. This method, not giving a very pure product, is not well adapted for many purposes. The method generally adopted is that of robbing sulphuric acid of one equivalent of oxygen by any convenient body. A mixture of strong oil of vitriol and charcoal heated in a flask, which has a conducting tube—Fig. 571—attached, serves very well, if absolutely pure gas be not needed. The gas given off by the mixture is a compound of SO_2 and CO_2 . The following being the reaction—



But sulphurous acid as nearly pure as possible, in fact quite pure, if made to traverse a little water to take up any sulphuric acid, may be obtained by heating sulphuric acid with one-third its weight of copper, in the shape of turnings or clippings. One atom of copper takes up one atom of oxygen from one atom of sulphuric acid, and becomes oxide of copper, which itself immediately combines with another equivalent of sulphuric acid, forming sulphate of copper—



Mercury may be substituted, but with no advantage—a like reaction takes place. The sulphurous acid so obtained is permanently gaseous at the ordinary atmospheric pressure, but is capable of assuming the liquid form, like carbonic acid, sulphide of hydrogen, and sundry other gases, at an increased pressure with a very low temperature. FARADAY employs a pressure of from three to five atmospheres; WACH places in a long glass tube, sealed at both ends and bent in the middle, a mixture of anhydrous sulphuric acid and sulphur. This is heated, while the opposite end is kept immersed in a freezing mixture. Sulphurous acid is formed under strong pressure, and condensed in the cooled end of the tube. In order to obtain it pure, it must be run to the other end of the tube, and again distilled to free it from sulphuric acid. Sulphurous acid in the liquid state is only of scientific interest; it is like many other rare chemical preparations, which are only made at a cost of great labor, and when made, can only be preserved conveniently for a very short time. As a liquid its boiling temperature is 14° .

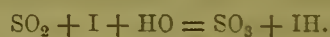
As far as all the useful properties of sulphurous acid are concerned, they may be studied from its solution in water, this liquid taking up, at mean temperature, thirty-three times its bulk of the gas.

Sulphurous acid solution is obtained by passing a stream of the gas through cold water, employing for the generation any of the methods just given. A series of WOLFF's bottles, or other convenient apparatus, may be employed for the condensation. The contents of the first bottle should always be rejected, as it will contain a considerable quantity of sulphuric acid, carried over both mechanically and in a state of vapor; the other will be a nearly pure solution of sulphurous acid.

Sulphurous acid is capable of forming a crystalline hydrate with water. It is procured by exposing sulphurous acid vapor with water, in a tube or other apparatus, to a low temperature, by placing this tube in a freezing mixture. Solid sulphurous acid may be procured by rapidly evaporating the liquid acid—it forms white flakes. It is heavier than the liquid, and freezes at *minus* 110° . It is composed of—

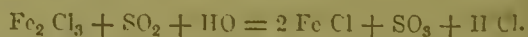
Sulphur vapor, ... 1
Oxygen gas, ... 6 } forming 6 vol. of spec. grav. 2.2114

Sulphurous acid is a powerful deoxidizer, instantly decoloring acid solutions of the manganates and chromates—in the latter case reducing them to the state of green sesquioxide of chromium. For analyzing the commercial sulphites, it is only necessary to weigh a stated quantity of the sulphite or hyposulphite to be examined, dissolve it in water, make it acid with hydrochloric acid, and then to note the number of measures of a normal solution of bichromate of potassa required to be added to convert the sulphurous into sulphuric acid, and data are obtained from which the amount of sulphurous acid contained in the sample may be easily calculated. This reducing property of sulphurous acid has been turned to advantage by BUNSEN, in the indirect analysis of various bodies—for instance, in the valuation of manganese. He places the manganese in a flask, treats it with hydrochloric acid, passes the evolved chlorine into a solution of iodide of potassium; each atom of chlorine sets free an atom of iodine. When the operation is over, he disconnects the vessel containing this iodine, and adds from a burette a normal solution of sulphurous acid until the precipitated iodine has disappeared. Each equivalent of iodine converts an equivalent of sulphurous into sulphuric acid, as follows—



Thus, tracing the reaction back, one equivalent of sulphurous acid represents one equivalent of biniodide of manganese—this principle is applied in a variety of ways. The deoxidizing power of sulphurous acid is taken advantage of by the chemist in the estimation of arsenic. When arsenic exists as arsenic acid, it is very slowly thrown down by sulphide of hydrogen; whereas arsenious acid is easily precipitated. Sulphurous acid possesses the power of abstracting part of the oxygen from arsenic acid, reducing it to arsenious; so that, if a stream of sulphurous acid be passed through the arseniate to be analyzed, after making it acid with hydrochloric acid, it is converted into arsenious acid, which facilitates its precipitation when one comes to employ sulphide of hydrogen.

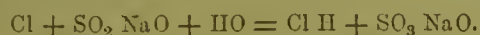
Sulphurous acid, passed through a dilute solution of yellow sesquichloride of iron, quickly reduces it to a protosalt—



Sulphurous acid reduces salts of gold, throwing down the gold in the metallic state. It is capable of taking up the second equivalent of oxygen from almost every metallic biniodide.

Sulphurous acid, in the shape of sulphite of soda, has been an article of commerce for some time, under

the half-fanciful and half-true appellation of antichlor. It has derived its name from the use to which it is applied, being used to correct the evil effects of an overdose of chlorine. In the bleaching of paper pulp, if any excess of chlorine or hypochlorite has been used, the sulphite, on being added, neutralizes it. If, for the sake of illustration, we imagine chlorine to have been used, then—



This hydrochloric acid can be taken up by any alkali, or will itself decompose a fresh portion of the sulphite, driving off sulphurous acid.

Sulphites are used by some in the manufacture of beet sugar. PROUST recommended them and a sulphurous acid solution as being antiferments, and having also other advantages. The following method of procuring it in large quantities was proposed by CALVERT, in a lecture lately delivered before the Society of Arts. He constructs a sulphur oven, such as is used in the manufacture of sulphuric acid. Within this oven the sulphur is burned, producing sulphurous acid. An earthenware tube, immersed in water, leads from this burner or oven to a tall wooden column filled with pumice-stone, or other suitable porous body. A cistern of water is placed on the top of this column, to which cistern a tap or valve is attached, by means of which a shower of water can be sprinkled on the pumice-stone, keeping it in a moist or wet state. The mixture of gases issuing from the burner, consisting of sulphurous acid, atmospheric air, and residual nitrogen, pass along the conducting tube, enter the column near the bottom, and pass up its whole length, thus meeting with the descending water; the sulphurous acid is absorbed, and a constant stream of the solution issues into a cistern placed at the bottom for its reception, while the residual gases pass out into the atmosphere.

Some brewers employ a solution of sulphurous acid to rinse out beer barrels after washing, as it possesses the property of arresting the acetic fermentation.

Sulphurous acid, when present in a free state in small amounts, is easily detected by its suffocating odor. It does not, like sulphuric acid, give any reaction with a salt of baryta, except when combined with a base. This is on account of the sulphite of baryta—unlike the sulphate—being soluble in free acid. When sulphuric acid is added to a salt of baryta, sulphate of baryta is formed, and the acid with which the baryta was previously combined is set free. But this acid can exert little or no action on the sulphate of baryta. Now, on adding sulphurous acid to a salt of baryta, the sulphite of baryta would dissolve in the acid set free, and which was previously combined with the baryta. But in the case of a salt having sulphurous acid in its composition, this does not occur. No acid is set free to exert a solvent action. For instance, if to a solution of chloride of barium is added a solution of sulphite of soda, a white precipitate of sulphite of baryta will be produced—



Supposing it to have been doubtful whether the salt employed was a sulphite or a sulphate, one can now determine the point by the addition of an acid, say

hydrochloric acid. Sulphite of baryta being soluble in this acid, the precipitate will disappear if the salt was a sulphite; if the precipitate is persistent, a sulphate is indicated. Of course, both may be present.

An old specimen of sulphite is sure to contain a quantity of sulphate, formed by oxidation, even though pure originally. To determine absolutely the presence or absence of sulphurous acid in a body, it is only necessary to dissolve it in hydrochloric acid, if solid, or if a liquid, make it acid to the same extent, and add a few scraps of zinc, such as is used in the production of hydrogen gas. If the body under examination contain sulphurous acid, the hydrogen going off will be accompanied by sulphuretted hydrogen, which may be detected by the smell, or by its blackening paper dipped in a solution of a lead salt. This test will discover very minute quantities of sulphurous acid. Such is its delicacy that sulphurous acid may be detected in much of the commercial hydrochloric acid; it arises from the action of the strong sulphuric acid on the iron decomposing vessel employed. The reaction may be explained as follows, leaving out the hydrochloric acid:—



One method of estimating sulphurous acid has been given, but the ordinary method is to convert it into sulphuric acid, and then proceed in the manner followed in the estimation of that acid. This may be effected by several oxidizing bodies. It is sometimes recommended to employ nitric acid, but there is a chance of error by doing so, inasmuch as a quantity of the sulphurous acid may escape whilst heating it. Perhaps the best method is to pass through the sulphurous acid or the sulphite to be analyzed a current of chlorine until the liquid smells of the latter gas, placing it on a sand bath until all smell has disappeared, then precipitate with a salt of baryta, collect, wash, ignite, *et cetera*, exactly as indicated under the head SULPHURIC ACID.

Sulphurous acid forms, with bases, a series of salts called sulphites, one of which has been already mentioned, the sulphite of soda. These sulphites have been shown by the Editor to bear a strong resemblance to carbonates, being also isomorphous with the latter salts. The following list proves the analogy:—

Sulphites.	Carbonates.
KO, SO ₂ + 2 HO	KO, CO ₂ + 2 HO
KO, SO ₂ + HO, SO ₂	KO, CO ₂ + HO, CO ₂
NaO, SO ₂ + 10 HO	NaO, CO ₂ + 10 HO
NaO, SO ₂ + HO, SO ₂	NaO, CO ₂ + HO, CO ₂
NaO, SO ₂ + HO, SO ₂ + 8 HO	NaO, CO ₂ + HO, CO ₂ + 8 HO
BaO, SO ₂	BaO, CO ₂
SrO, SO ₂	SrO, CO ₂
MgO, SO ₂ + 3 HO	MgO, CO ₂ + 3 HO
MnO, SO ₂ + 2 HO	MnO, CO ₂ + 2 HO
PbO, SO ₂	PbO, CO ₂
AgO, SO ₂	AgO, CO ₂

Sulphite of soda is the only salt—with the exception of a mixed sulphite of lime and magnesia—which is manufactured on a large scale. Sulphite of soda is made by passing a stream of sulphurous acid gas through a solution of carbonate of soda; the carbonic acid is displaced, and sulphite of soda is formed. On the large scale, the same method as is pursued in the

manufacture of bicarbonate may be followed for the production of the sulphite. A chamber or suitable large vessel is so constructed with appliances that a stream of sulphurous acid from burning sulphur may be drawn through. This chamber or vessel is filled with crystals of carbonate of soda; the stream of sulphurous acid in its passage through the interstices of the mass is taken up, carbonic acid being evolved. The passage of the gas must be continued until a sample taken out of the chamber, on being dissolved, has an acid reaction with litmus paper. The mass of what was originally carbonate of soda has now become a mixture of sulphite and bisulphite of soda. This is now dissolved in water, and brought to the boiling point; a solution of carbonate of soda must now be added, until the last addition causes no evolution of carbonic acid; the whole is now brought to the state of neutral sulphite; and after standing to deposit any mechanical impurities may be run off into a suitable vessel to crystallize.

The sulphites of potassa and ammonia may be prepared in a similar manner to that of soda, by passing sulphurous acid through a solution of the alkalies or their carbonates.

The sulphites of the alkaline earths are prepared either by exposing the moistened, or better, the hydrated oxides, to gaseous sulphurous acid, when this gas is absorbed; or the oxides or carbonates may be suspended in water, and a stream of sulphurous acid passed through; or they may be produced by double decomposition from a soluble alkaline sulphite, and a chloride of the earthy metal. These sulphites are all more or less nearly insoluble in water and alcohol, but are rendered more soluble by an excess of sulphurous acid, in this respect resembling the carbonates. The only practical purpose to which any of these earthy sulphites have been applied, is as disinfectants. For this purpose, a mixture of the sulphites of lime and magnesia is used. Mr. M'DOUGALL seems to have a method of producing sulphites much more readily than any other maker.

The sulphites of the metals proper, such as iron, zinc, lead, bismuth, *et cetera*, are produced by analogous processes; they, like the earthy sulphites, are more soluble in a solution of sulphurous acid than in pure water.

SULPHURIC ACID—*acid sulphurique*, French; *schwefelsäure*, German—is the most stable and the best known oxide of sulphur. It appears to have been known from very early times. BRANDE, in speaking of it, says that the honor of its discovery is due to BASIL VALENTINE. He frequently mentions it and its mode of preparation; and PARACELUS, and the authors who immediately followed, talk of it as well known and in common use, though it is probable that it bore a high price, and was but scantily supplied by a few awkward and unintelligent operators. But KOPF shows evidently that VINCENTIUS DE BEAUVAIS had an idea of the substance obtained by distilling alum. BOYLE first recognized in it a relation to sulphur. MAYOW pointed it out with great clearness, but he was far before his time in penetration. STAHL believed sulphur to consist of sulphuric acid and phlogiston, a theory in conformity with the rest of his system.

LAVOISIER showed the formation of acid by sulphur taking up oxygen, but it had been made by burning sulphur in the air, at least since the time of LEMERY and Dr. WARD. Sulphuric acid exists, as free acid, in two states, liquid and solid—the liquid being a combination of dry acid and water. The right of the dry body to be called sulphuric acid is doubted, as it exhibits no acid characters until combined or mixed with water. The character of the acid is sufficiently shown in the reactions of the monohydrated sulphuric acid— $\text{SO}_3 \cdot \text{HO}$ —or the purified oil of vitriol. The body is a heavy fluid, above three-fourths heavier than water. It flows when poured from one vessel to another, in a heavy, smooth, *oily* stream. This oily appearance has, doubtless, given it its name; and although this appellation, oil of vitriol, has been much ridiculed, it cannot be disputed that it is very expressive, and serves well to distinguish the strong vitriol from the dilute acid, which bubbles like water when poured. Oil of vitriol has a strong attraction for water, so much so that a bottle containing it, if left open, rapidly attracts moisture from the air, becoming itself much weaker. This property is often taken advantage of in analytical operations. When a stream of dry gas is needed, it is simply requisite to pass it through strong sulphuric acid, or through a wide tube filled with fragments of coke or pumice-stone saturated with the acid. This is a very effectual mode of drying a gas. It is not applicable to certain gases, between which and the sulphuric acid a reaction might take place. In the simple and elegant apparatus, devised by FRESNIUS and WILL, for the estimation of carbonic acid, sulphuric acid is employed for the purpose of desiccating the carbonic acid before it emerges from the apparatus. It has been stated that sulphuric acid possesses the property of absorbing carbonic acid, and that consequently the operations in which its drying property has been taken advantage of cannot be correct. This, again, has been retorted: and, inasmuch as most chemists are in the habit of using this apparatus, it would appear to be tacitly allowed that if any error from this source does exist, it is so small as to be of no consequence.

This attraction of sulphuric acid for water also brings about some curious decompositions with organic bodies. For instance, if any of that class of bodies, such as sugar, starch, *et cetera*, which contain carbon, hydrogen, and oxygen, in such proportions that, for the sake of simplicity, they may be considered as being composed of carbon and water, be mixed with strong sulphuric acid, and heated, a black mass will be obtained; and if this mass be thoroughly washed with water, so as to remove every trace of sulphuric acid, it will be found to be pure carbon, the whole of the elements of water having been removed. So effectual is the process, that the principle has been proposed as a method of obtaining peat charcoal without the ordinary charring process. This charcoal is then washed and dried. To this same property is due the occasional brown color of commercial vitriol. If particles of organic matter fall into it, a portion of their hydrogen and oxygen is abstracted, forming a humus-like body, which, dissolving in the vitriol, colors it. This attraction for

water seems to be the principle by which it acts upon the skin, and animal and vegetal matter generally. The density of this monohydrated acid is 1.850, and it boils at a temperature of 620°. Its boiling point diminishes with its density. The strong acid is perfectly volatile, and thus capable of being distilled. It freezes at a temperature of 29°, yielding often six-sided prisms of a tabular form.

This acid has the power of supplanting or displacing almost every other acid known, so great is its affinity for bases. It produces great heat when mixed with water, the compound becoming denser than the mean of the two liquids. If equal volumes of strong sulphuric acid and water be mixed, and then allowed to cool, it will be found that the resulting liquid will not make up the original two volumes; it now occupies less space, contraction having taken place. During this contraction a portion of the latent heat of the water has been given off. PARKES made a series of experiments on this matter, the results of which are given in the following table:—

HEAT PRODUCED BY THE ADMIXTURE OF SULPHURIC ACID WITH WATER, TEN POUNDS OF SULPHURIC ACID BEING USED IN EACH EXPERIMENT.

Sulphuric acid in pounds.	Temperature of the mixture in degrees of Fahrenheit.
1	78°
2	100
3	110
4	128
5	138
6	144
7	156
8	168
9	186
10	204
11	214
12	222
13	229
14	236
15	241
16	246
17	250
18	253
19	256
20	258
25	266
30	264
35	254
40	248

But FAVRE and SILBERMANN have lately examined the question more thoroughly, and shown that the following amount of heat is given out:—

HEAT EVOLVED BY MIXING SO_3 HO WITH WATER.

Atom of water.	Heat units.	Differences.
With the first $\frac{1}{8}$	94.0	0.6
second $\frac{1}{8}$	88.0	
With the first $\frac{1}{4}$	18.8	1.6
second $\frac{1}{4}$	17.2	
With the first $\frac{1}{2}$	36.7	8.4
second $\frac{1}{2}$	28.3	
Atoms of water.		
1	64.7	29.9
2	94.6	17.3
3	111.9	10.3
4	122.2	8.5
5	130.7	5.5
6	136.2	4.4
7	141.8	3.3
8	145.1	3.4
9	148.8	0.0
10	148.4	0.0
20	148.6	

When four of the monohydrate are mixed with one of water by weight the temperature rises to 300°.

GRAHAM gives the following list of the hydrates of sulphuric acid—

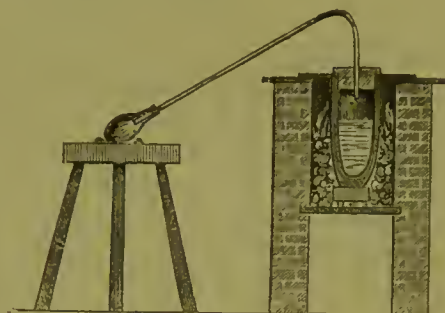
Nordhausen sulphuric acid,	= HO, 2 SO ₃
Sulphuric acid, specific gravity, 1.850,	= HO, SO ₃
“ “ 1.78,	= HO, SO ₃ + HO
“ “ 1.632,	= HO, SO ₃ + 2 HO

The third hydrate in the above list corresponds nearly to the commercial brown oil of vitriol, the density of this latter being 1.758. It is formed by heating a dilute acid to 400°. Its properties are almost identical with those of the monohydrate. It has the property of solidifying at the temperature of melting ice, or a little above this point. It is no uncommon circumstance for a sulphuric acid manufacturer to find a carboy of brown vitriol converted almost into a mass of crystals, if exposed to the cold in frosty weather. These crystals are the well-defined hydrate in question. This crystallization has been proposed as a method of obtaining pure sulphuric acid, as will be seen hereafter. Little seems to be known of the lower hydrate. It is formed by heating a dilute acid at 212°. This amount of acid and water causes the greatest condensation of volume.

Neither dry nor fuming acid can be obtained by the ordinary mode of concentration, it being impossible to drive off the last equivalent of water. Dry acid may be obtained by distilling the Nordhausen acid—HO, 2 SO₃. But Nordhausen acid is not now a common commercial product; it is often necessary for the operator to make his own. This may be done either by distilling the protosulphate of iron or the sesquisulphate, artificially prepared; bisulphate of potassa or soda may be also used. This latter salt is the cheapest, and perhaps the most convenient. It may be procured by heating one equivalent of common salt in a crucible with two equivalents of sulphuric acid, taking care to operate under a chimney, or in some situation where the hydrochloric acid fumes will be carried away quickly. When gas has ceased to be evolved from the mixture, the residue must be heated to a low red-heat, in order to drive off as much water as possible. The fused salt must be removed from the crucible and allowed to cool. This may be done by pouring it out into an iron dish, or other convenient vessel. When cold, it must be broken up, when it is ready for the next operation. Or, instead of this, the bisulphate of soda or potassa left in the retorts, when procuring nitric acid, may be preserved for the same purpose. Porcelain retorts being very expensive, it is well to substitute, if possible, some cheaper piece of apparatus. For this purpose an ordinary brassfounder's crucible may be employed; a lid may be formed out of a piece of ordinary fire-tile—this lid has a hole cut through, into which is inserted a piece of glass tube to carry off the vapor. The arrangement is shown in Fig. 571. To commence, a piece of brick is first laid on the bars of the ordinary laboratory furnace; on this the crucible is placed; this is filled with the broken pieces of bisulphate; the lid is luted on with clay, and the tube luted into the lid. A fire is lighted around the crucible, and this is gradually increased in power, until at length

distillation commences. Weak acid at first comes over—this is emptied out of the receiving flask; eventually the retort or crucible begins to attain a good red-heat; drops of strong acid fall, and hiss as they touch the weaker acid in the flask. The flask is now

Fig. 571.



finally emptied of its contents, and replaced, the acid which now comes over being fuming acid, white vapors pour through the glass tube at a rapid pace, a portion condensing there, and a portion in the flask. The flask should be a thin one, and is all the better for being placed in a basin of cold water. After a time vapors cease to appear, and the operation is at an end. The glass tube should now be carefully taken away, as also the lid of the crucible, and the fused or softened mass, forming the contents of the latter, should be removed by means of an iron scoop. This done, the crucible should be allowed to cool slowly; when cold enough, it may be filled again, and the foregoing operation repeated. With care, a crucible will last three or four operations. The neutral sulphate may be reconverted into bisulphate, to be again employed.

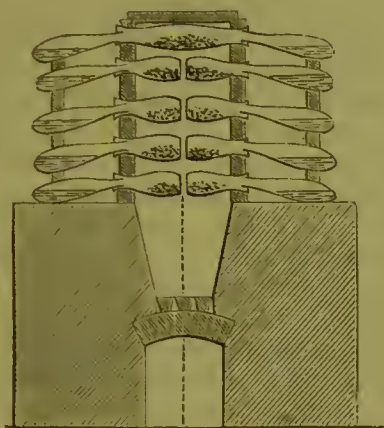
The fuming acid so obtained gives off white vapors. These white fumes are dry acid— SO_3 —vapor, combining with the moisture of the atmosphere. It makes a hissing noise when poured into water, very like the noise made when red-hot iron is plunged into a liquid. This acid is employed in gas analysis, on account of its possessing the power of absorbing certain hydrocarbons. For this purpose a piece of coke is wetted with the fuming acid and passed into the gas to be analyzed, standing in a graduated tube over mercury. To obtain the dry acid it is necessary to submit the fuming acid to distillation at a gentle heat. For this purpose a glass retort is partially filled with the fuming acid, the neck of the retort is inserted into a flask, placed in cold water, a gentle heat is applied to the retort, when the dry acid begins to come over. It condenses in solid fibres like asbestos, which are tenacious, and may be moulded by the fingers like wax. Its density at 68° is 1.970; at 77° it assumes the liquid state; and a little above that temperature it enters into ebullition. If a little of this *anhydrous* acid be placed on a slip of *dry* litmus paper no reddening results—coloration not taking place until moisture has been absorbed.

Manufacture of Sulphuric Acid.—The principle involved in the mode of working adopted by Dr. ROEBUCK, who may be considered the first inventor or improver, still continues in vitriol manufactories; in fact, from that time may be dated the actual rise of the sulphuric acid manufacture.

The earlier process, and, according to many authorities, the one still followed in a few places where its advantages render it profitable, is one already alluded to, and which consists in distilling or driving off by intense heat the sulphuric acid from protosulphate of iron. This salt is dried and placed in fireproof retorts, which are built in suitable furnaces. Proper receivers are connected with them. These retorts are charged, and heat applied, until they become sufficiently hot. The sulphuric acid is driven off and condenses in the receivers, while oxide of iron is left in the retort. The following description, extracted from KNAPP's excellent work, will give a good idea of the process as followed at Radnitz:—The material operated upon is the mother liquor from the manufacture of alum. This contains a large quantity of protosulphate of iron. These mother liquors are first evaporated to a dry state, and then roasted at a gentle heat. During this latter roasting a considerable quantity of oxygen is absorbed, the protosulphate passing partially into basic persulphate of iron. These operations are conducted on the spot where the alum liquors are to be had. This roasted product, which is called *vitriolstein*, is sent to Radnitz for conversion into fuming oil of vitriol. This process consists in the dry distillation of the *vitriolstein*. The pots in which the distillation is effected are constructed of refractory stoneware, and after being baked in a kiln upon the premises, are about nine inches long, two and a half inches in diameter at the bottom, four and a quarter at the middle, and three inches at the mouth; they are about four-tenths of an inch thick in the sides. Before being used they are covered with a lute, or luting material, which is easily fritted by the action of the fire. The receivers are of much the same shape, but are longer and narrower at the mouth. The upper row in the furnace is occupied by a single range of pots twenty-eight inches in length. The gallery furnace for the reception of the pots is rectangular in section, and is composed of two parts essentially distinct. The lower part is built of massive masonry, enclosing the ash-pit and the grate, which extends the whole length under the range of pots: the upper part consists of two vertical walls of perforated brickwork, which form the sides of the furnace and support the pots. This latter portion demands frequent repair. Fig. 572 represents a front vertical section. It incloses four tiers of the smaller sized pots, arranged with their bottoms in contact, and an upper tier of long pots, which extend from one side of the furnace to the other, and are open at both ends. The whole, therefore, contains two hundred and eighty-eight pots—thirty-two large, and two hundred and fifty-six small. The long sides of the furnace are divided into squares by vertical and horizontal bricks of the same dimensions, and four pots are placed in each square, separated from each other by small bricks, the interstices being luted with refractory clay. The arch of the furnace is constructed of flat bricks, simply placed alongside each other, and cut sloping at their extremities, to allow the flame to pass. A small chimney is sometimes built to the furnace, but it is more frequently without. The pots are charged with the *vitriolstein*, previously broken up with a hammer, by means of a

semicylindrical spoon, each pot receiving two spoonfuls. The coal for the first charge is then ignited below the grate, and is thrown upon the grate at the expiration

Fig. 572.



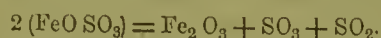
of about an hour or an hour and a half; the fire being carefully regulated by opening or shutting the doors. At the end of four hours the lower tier of pots is brought to a dark-red heat. The receivers are successively introduced into the pots and luted, those of the second layer resting immediately upon the first, and a wooden support being introduced between the second, third, and so on. The receivers are slightly inclined, and a small quantity of water is placed in each. This is sufficient to receive the acid from four successive distillations, after which it is in the state of concentration required in commerce. The fire is gradually increased, and after from thirty to thirty-six hours no more acid is evolved from the upper tier of pots, and the distillation is finished. The whole is then allowed to cool for twelve hours, and the receivers being removed the colcothar is taken from the pots. This contains about six and a half per cent. sulphate of lime, and amounts to about thirty or thirty-five per cent. of the vitriolstein employed.

The pots are now examined by the sound which they emit when struck. The broken ones are removed, and being replaced by fresh pots, the distillation is recommenced.

Each operation lasts about forty-eight hours, and three are completed in a week. From forty-seven to fifty per cent. of the vitriolstein is obtained in fuming sulphuric acid; five parts of coal are consumed for one part of vitriolstein distilled. About thirty pots and three receivers are replaced after each distillation, which is equivalent to 10.42 and 1.04 per cent. respectively.

Although such a mode of manufacture may be capable of being followed in some localities, yet it is far from possessing the general adaptability of the ordinary process. From the above description there appears to be little loss, except from accidental leakage or the breaking of a pot; but as the process is described by many, or in fact the greater proportion of writers, simply dry protosulphate of iron is employed— FeO SO_3 —not as in the method just described, sesquisulphate— $\text{Fe}_2\text{O}_3 \cdot 3\text{SO}_3$ —or rather a basic persulphate. The employment of one or the other must make a considerable

difference in the amount of product obtained, for if any protosulphate of iron be employed, only one half of the sulphuric acid contained in it will be obtained as *sulphuric acid*, the rest passing off as sulphurous acid. The following is the reaction:—



Two equivalents of protosulphate of iron are decomposed into one equivalent of sesquioxide, one of sulphuric acid, and one of sulphurous acid; one of the equivalents of sulphuric acid has parted with one of its equivalents of oxygen, in order that the two equivalents of protoxide of iron might become sesquioxide. This equivalent of sulphurous acid is said to escape through the joints of the apparatus; if so, and there does not appear to be any doubt of this being the fact, inasmuch as no other provision appears to have been made for its exit, one may naturally conclude that sulphuric acid vapor must escape at the same time.

Such was the method pursued for procuring sulphuric acid for some centuries. The next process—a modification of which remains in use to this day—consisted in converting sulphur by stages of oxidation into sulphuric acid. This differs materially from the process before described, in which acid already formed was simply separated from a combination; in the present case the operation commences with the prime element. The first step in this direction appears to have been the formation of sulphuric acid in small quantities by the combustion of sulphur in glass globes, moistened on the interior surface with water. It is true that under these circumstances a small quantity of sulphuric acid would be formed, but the amount would be very minute indeed; in fact, the combustion of sulphur in pure oxygen gives rise to little more than a trace. But a grand step was made in the right direction by the introduction of nitre in the manufacture. The use of sulphur and nitre together was said to have begun with LEFEVRE and LEMERY. Dr. WARD had the monopoly of it long in this country, and best knew how to manage the process. Instead of sulphur *per se*, a mixture of sulphur and nitre was made, and set fire to in or under a bell glass; by this proceeding a much greater quantity of sulphuric acid was obtained. It can easily be imagined, that even the most successful experiment could furnish only a small quantity of acid, on account of the very limited size of the apparatus. This must strike an observer when he contrasts in his own mind the largest jar or globe that could be blown, even now, with one of the vitriol chambers of the present time. But this difficulty of limited dimensions was surmounted by a Dr. ROEBUCK of Birmingham, who was the first to introduce leaden chambers, which he did as a substitute for the comparatively small globes; and as he was able to make them of any required size, a great relief must have been given to the manufacture. The manner of working was still precisely similar to that with the globe. The chamber had an entrance-door, which could be luted tight; this was opened, and a charge, consisting of a mixture as before of sulphur and nitre, was put on a proper stand placed to receive it in the chamber. According to some authors this was a sort of carriage, which could be pulled towards the door to receive the

charge, and then after ignition pushed towards the centre of the chamber; but it is difficult to conceive that this is true, as it would not be easy to find material of which to construct the wheels and other parts of such a machine, when it is considered that the floor of the chamber was covered with acid to the depth of several inches. It is certain that the proper charge was placed on a stand in the interior of the chamber; this was ignited, and the door was then properly fastened and luted. After a certain time had elapsed the door was again opened, and the residual gas or gases allowed to escape. This was repeated again and again, until the water with which the floor of the chamber was covered had absorbed sufficient of the acid, when it was run off and concentrated. Authors speak of a collapse of the sides of the chamber occurring, owing to the partial vacuum produced by the absorption of the oxygen of the contained air. But it can be scarcely believed that this accident could have occurred often, since it is hardly conceivable that practitioners of the chemical art at that time could have been ignorant of the fact that a very simple arrangement of a water-valve opening inwards would have remedied this.

This process, then, was the one followed by Dr. ROEBUCK, and such in principle it remains down to the present day; and had it possessed the advantage of a later invention, *videlicet*, the introduction of steam, it would no doubt have given an excellent result. Supposing there had been in the chamber twenty-four parts by weight of oxygen for every sixteen parts of sulphur introduced, watery vapor being also present in sufficient quantity, every particle of sulphur must have been converted into sulphuric acid, if sufficient time were allowed to elapse before the opening of the chamber door.

Having followed the manufacture to this point, one must now pass on to another step, from the intermittent to the continuous process, as practised at present. It is easy to see that had Dr. ROEBUCK burned his sulphur in a properly constructed apparatus, and introduced the resulting sulphurous acid into his chamber at one end, drawing off the residual gases at the other, he would have improved his method, and escaped many inconveniences.

If one views the gigantic scale in which this manufacture is carried on at the present day, by a TENNANT or a MUSPRATT, he must smile on looking back at the almost puny manner in which they operated in former times; but, then, add to their process the continuous system—the introduction of steam into the chambers by KESTNER, concentration in the platinum vessels, and GAY-LUSSAC's column for the recovery of the nitrous gas—and manufacturers have almost all that could be desired at present.

Much ingenuity has been expended in the construction of every piece of apparatus connected with the manufacture of vitriol. The ovens or burners, the chambers, and every part, have been tortured into a variety of forms, some of which would appear to have been devised in an idle moment, and constructed only to gratify a whim, or if any object has really been in view, it must have been imaginary. But in every manufactory where the process is understood, the difference,

except in little details, between the apparatus of to-day and that of twenty years ago, is very small. Improvement after improvement, which have turned out to be rather impediments, have been introduced, had their short reign, and disappeared, only to be succeeded by something else equally visionary. In fact, it would seem that the manufacture of sulphuric acid, though as extensively carried on as any business, yet seems to be the least understood; and the ignorance of some manufacturers appears to be only equalled by that of writers who, in their descriptions of the production of this acid, give figures of apparatus, and vaunt as improvements things which have been exploded for years. It is possible to find, in the works of eminent men, drawings of sets of apparatus for the production of sulphuric acid, *which never could possibly have worked one day*—some, in fact, could never have worked at all.

Production of the Sulphurous Acid.—This first step is effected by burning the sulphur in a close room or oven,

Fig. 573.

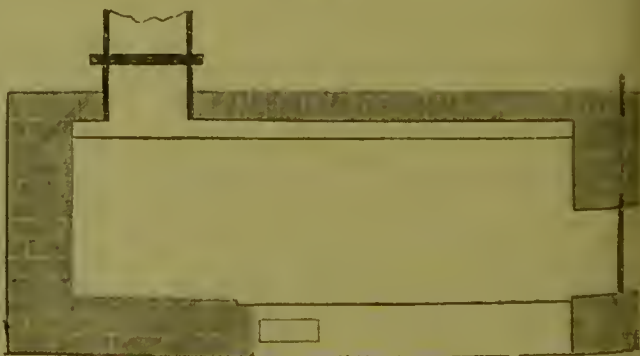


Fig. 574.



commonly called a burner. This burner is a simple erection of brickwork, with an arched roof, as shown in Figs. 573, 574, and 575. The size of the burner is regulated by that of the burner plate or iron flooring, and this latter by the quantity of sulphur proposed to be burned during seven days. The burner plate in the drawing is a rectangular iron, measuring eight feet by four feet. This burner plate is surrounded with a vertical edge or border, standing about an inch high: this border is at right angles to the plate on three sides, but on the fourth side, the one nearest to the door, it inclines outwards at an angle of about forty-five degrees—this is for the more conveniently raking out of the residual dirt and ashes left after the combustion

Fig. 575.



of the sulphur. The door of this burner is simply an iron plate, sliding in grooves in an iron framework, and is counterbalanced by a weight hanging at the end of a chain, which passes over pulleys.

As will be seen in the figure, the iron plate does not form the whole of the floor; still the sulphur is burned on it alone. The object of making the burner rather larger than the plate is to avoid, as much as possible, all risk of sublimation. To this end, also, there is a constant current of air passing beneath the burner plates and up a small chimney beside the burner. The opening through which the hot air escapes into this chimney is outlined in Fig. 575, below the burner plate. Four burners, such as this, with the burner plates of the size first mentioned, will easily convert into sulphurous acid one ton of sulphur per twenty-four hours. The quantity for each burner is divided into six portions, one of which is added every four hours.

Burners or ovens have been constructed of iron, sometimes with double sides, so as to include a sheet of air between the two plates. By this means the burners could be kept at almost any desired temperature; an arrangement could be made for causing a circulation of air if the burner should get too hot, or, on the contrary, should they get too cold, this air could be kept stagnant, and being a very bad conductor of heat, the burner would be allowed to rise to the desired temperature. It may be remarked here, that a burner should be kept so hot that each charge of sulphur, as thrown in, will ignite without any fire or heat being applied.

Iron ovens or burners have, however, almost disappeared, as they last a very short time. They gradually corrode, break into holes, and shortly become useless.

Some years ago a patent was taken out for a burner, the peculiar feature of which was its economizing, and converting to a useful purpose, the heat given off by the burning sulphur. The apparatus was very simple. It consisted of an ordinary two-flued steam boiler, for the usual fire-place of which was substituted a burner plate on which to burn sulphur. It was anticipated that by this means sufficient steam would be generated to supply the chambers. Whether it answered the desired end or not is not very clear; but from the fact that none appear to be in operation, it may be inferred that, if in use at all, it is not generally successful. In fact it is very probable that the action of the acid gases upon it would speedily destroy it, as it does the iron burners.

Combustion of Iron Pyrites.—Sulphur, *per se*, is not the only source of sulphurous acid for sulphuric acid. About the year 1835 the then King of Sicily thought fit to impose such a heavy duty on all sulphur exported from his kingdom, that the price of this article rose to an unprecedented height. It is said that at this crisis Dr. THOMAS THOMSON proposed the employment of the iron pyrites, with which different parts of this kingdom abound, as a source of sulphur. PARNELL states that Mr. HILL of Deptford was the first to employ this mineral, for the use of which he took out a patent in 1818. Since that time pyrites has come into very general use amongst one class of sulphuric acid manufacturers. The great objection to the use of pyrites lies in its containing a considerable amount of arsenic. This renders the vitriol objectionable for certain purposes, but this impurity does not prevent

its being used by the alkali manufacturers. A manufacturer of vitriol for sale would, were he to use pyrites, very likely have a quantity of his acid returned to him, and he would presently have to stop his manufactory. Not so the soda manufacturer; he is his own vitriol consumer—he uses all the acid he makes for the decomposition of common salt in the first step of soda-making. In his case the arsenic does not interfere in the least, it passes off as chloride of arsenic— AsCl_3 —with the hydrochloric acid gas, and condenses into a liquid state with this latter body. Again, most manufacturers of soda are also manufacturers of chloride of lime. In this case they use up their own hydrochloric acid, employing it for the production of chlorine, which is absorbed by hydrate of lime, forming the bleaching powder of commerce. If a little of the arsenic should pass over with the chlorine, it would be absorbed by the lime, forming an insoluble compound, arseniate of lime, which would fall out, with other useless matters, when the bleacher came to make his solution. The greater portion of the arsenic would remain with the chloride of manganese, and as at present this is a useless product; it is run into the nearest gutter or sewer.

The burning of pyrites is not quite so simple a matter as the burning of sulphur, as a red heat is required. Two varieties of pyrites are ordinarily met with. One kind, of which large quantities are to be found in Wicklow, Ireland, and is imported into this country, to a considerable extent, for the use of sulphuric acid manufacturers, has the crystalline form of a cube, and is of a bronze-yellow color, very hard, so much so as to strike fire with steel. The following is the composition of a specimen, on the authority of R. D. THOMSON—

	Centesimally.
Sulphur,	47.41
Iron,	41.78
Copper,	1.93
Arsenic,	2.11
Silica,	3.93
Zinc,	2.00
Insoluble matter,	1.43

This specimen is of a much richer kind than that usually obtained from this source. The proportion of sulphur very rarely exceeds thirty per cent. This ore contains protosulphide of iron in considerable quantity. The other variety of pyrites occurs in coal beds, and, in fact, is commonly known as coal brasses, fragments and seams of this mineral, may often be seen in coal, and, from their metallic and brassy appearance, have often misled the ignorant into thinking them of much greater value than they really are. According to the just quoted authority, they have the following composition:—

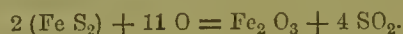
	Per cent.
Sulphur,	53.35
Iron,	45.07
Manganese,	0.70
Silica,	0.80
Loss,	1.8
100.00	

A variety of pyrites, known in the trade as Spanish pyrites, has of late been much employed. This is much richer in copper than the Wicklow species. On the introduction of this mineral, it was usual for the sulphuric acid manufacturer to engage to return the

spent or burnt material, for the purpose of having the copper extracted.

The general formula of either variety, when free from impurity, is Fe S_2 , that is, one equivalent of iron combined with two equivalents of sulphur, the chemical name of this compound being bisulphide of iron.

This mineral, when heated red hot, with access of oxygen, speedily loses the second equivalent of sulphur, being reduced to a simple or protosulphide— Fe S —the evolved sulphur being converted into sulphurous acid. If these favorable conditions are continued for a sufficient length of time, the second equivalent also becomes converted into sulphurous acid, sesquioxide of iron remaining. The whole decomposition may be represented as follows—



As may be imagined, the ordinary burner, as used for sulphur alone, lately described, is not adapted to burn pyrites; a burner of peculiar construction is required. The burner for this purpose is, in general structure, not unlike a lime-kiln. In the case of burning sulphur itself, the object is to spread a layer on a flat plate, so that, when fused and burning, it exposes a large surface for the current of air to sweep over; this is necessary on account of the fusion of the sulphur. But pyrites does not fuse except at a very high heat. The pieces retain their shape; and as it is imperative that they shall attain a red heat, it is necessary to burn them in such a manner that a mass of them can be kept together.

The structure of a pyrites kiln is shown in Figs. 576 and 577. In Fig. 577 the pyrites is shown as inclosed on two sides by two sloping walls, the back and front walls being vertical. The mass of pyrites rests on

for the purpose of arresting, as much as possible, the passage of arsenical vapors. The arsenic falling in a solid state is removed from time to time. Fig. 576 is a view of one of these kilns looking in another direction, endwise; *a* is the charging door through which fresh supplies of the mineral are thrown in at wide intervals. This door is kept closed, except for this purpose. At *b* another opening exists, but this is usually closed temporarily with bricks—it is only occasionally used. Sometimes the combustion goes on at a rate so rapid that the pyrites becomes fritted, or enters into a semifused state. Sometimes the whole mass gets fused together by its points of contact. In such a case the brick closure is removed for the purpose of introducing a crowbar, or other such instrument, in order to break up the mass or create a passage through it. The coal pyrites is much more liable to this melting than the Wicklow variety, partly on account of the bisulphide contained in it being actually rather more fusible, and partly because the coal brasses contain a certain amount of bituminous matter, which, in burning, raises the heat of the whole mass to a higher point than the Wicklow kind ever attains. The orifices, *c* and *d*, are those through which the sulphurous acid passes either into the next kiln or into the general passage.

It is not usual to see an isolated single pyrites kiln; there are often a number at work. Two are placed at the back of those shown in the drawing, forming a solid square. This answers a double purpose—it economizes brick and iron, and conserves the heat.

When commencing to burn, it is necessary to make a fire of coal or coke within the burners, having previously closed up the passage or entrance into the chamber, and opened one into the outer air. This fire heats up the sides, *et cetera*, of the kiln, high enough to ignite the pyrites when thrown in. The first few charges of pyrites are often mixed with coke to assist the combustion, until the whole mass has attained a red heat throughout. The carbonic acid resulting from this can do no harm.

The residual mass left after burning, and which consists principally of sesquioxide of iron mixed with more or less protosulphide, was at one time rather an annoyance than of any value to the manufacturer; but at the present time many of them have erected furnaces for the express purpose of extracting the small percentage of copper which it contains.

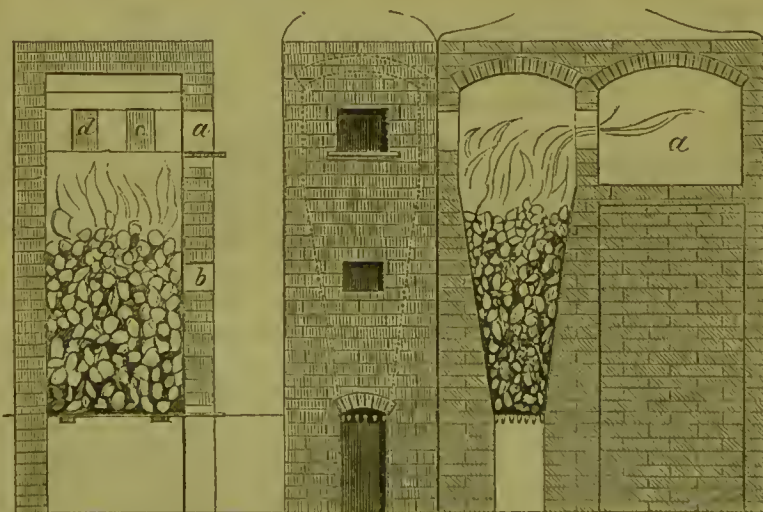
The quantity of sulphuric acid obtained from a given weight of pyrites of course cannot be as much as from sulphur, inasmuch as pyrites,

iron bars in the same manner as an ordinary coal fire, the air rushes up from what, in the case of an ordinary furnace, would be the ash-pit, and wends its way through the crevices and interstices of the mass to feed the combustion. The sulphurous acid from the first kiln passes over the next in the direction of the arrows, the gases from both flowing into the general passage, *a*, leading to the chamber. This general passage is often made of a considerable length, usually of from thirty to forty feet. This extreme length is

to take a general average, will not contain more than forty per cent. of sulphur; as a rule, a corresponding amount of sulphuric acid is not obtained from it. Much care and attention is required to burn pyrites well. It is no uncommon thing to find, on examining the waste pyrites heap of a manufacturer, that a great quantity has been removed little more than half burned. On breaking a lump a core or kernel of raw mineral may often be found; whereas well burned pyrites should not contain more than two and a half to

Fig. 576.

Fig. 577.

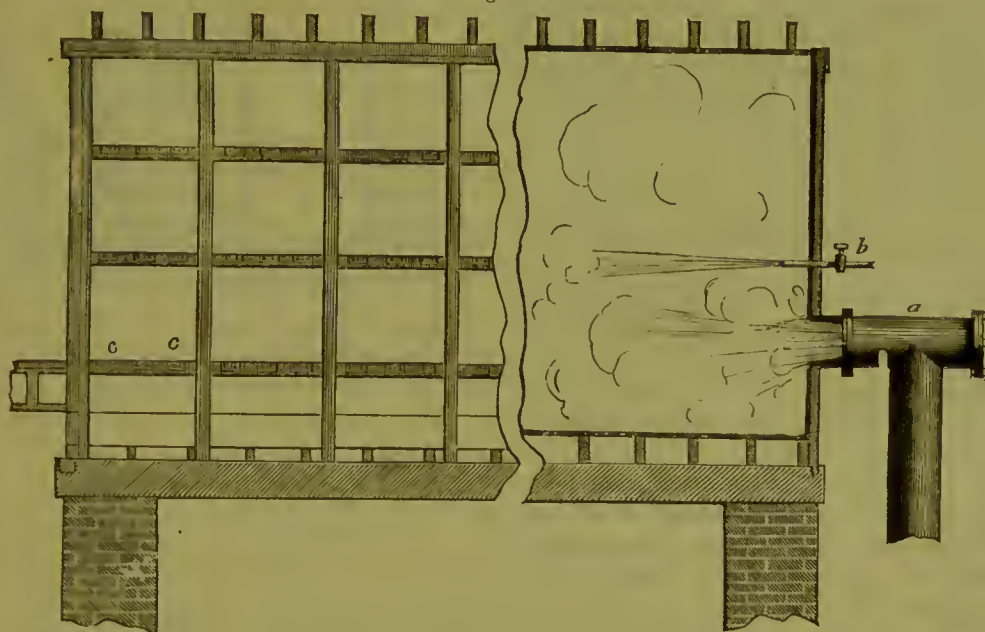


three per cent. of sulphur. Any amount more than this is in fact so much material thrown away.

General Construction of the Vitriol Chamber.—Having described the preliminary steps, the Editor now passes on to the chambers themselves. These have undergone many modifications. The chamber, as generally constructed, is simply a large room with leaden walls. A portion of one is shown in Fig. 578. These walls are generally formed of what is technically termed five-pound lead—that is, sheet lead weighing five pounds

per square foot—which walls are held up by a suitable framework of wood, to which they are fastened by what are called straps. These straps are pieces of lead, varying in number and size according to the dimension of the chamber. They are soldered or fastened by one edge to the sheet or sheets of lead forming the chamber side. The outer edge is pulled out over the wooden cross bar, and there nailed as shown at *a*, Fig. 578. The joints of the sheets of lead forming the chamber were formerly soldered with ordinary solder;

Fig. 578.



but this entailed a long series of annoyances in consequence of the action of the acid on the solder. The chamber leaked perpetually, and great inconvenience resulted. Eventually the expedient of welding was hit upon. This consisted in rolling the two edges of the sheets together and beating this flat; but this at last gave way to the method at present followed, *videlicet*, fusing the two edges of the sheet together by means of the oxyhydrogen blowpipe. For this purpose an apparatus is constructed which furnishes a constant and pretty strong current of hydrogen gas. This when mixed with a proper amount of atmospherical air projected from a pair of bellows furnishes the blowpipe. To use it the workman proceeds as follows:—He lays the edges of the two sheets together as closely as possible; every particle of dirt and oxidized or tarnished surface is scraped off; the flame is now applied in a peculiar manner, acquired by practice, and the two edges are joined together; thus making a solid joint of pure lead, as incapable of being acted upon as any part of the sheet. The plumbers who undertake the erection of these chambers are able to join two sheets of lead together even when the joint is in a vertical direction; but as it is rather a difficult and tedious business, they contrive to do as much as possible of it in a horizontal direction.

No rule can be given for the shape or dimensions of a chamber. Manufacturers are guided partly by convenience, partly by the size of the lead sheets procurable, and partly by a desire to have as much space as

possible included in the chambers with the least expenditure of lead. It is with this view that many chambers of vast size, and in shape as near as possible a cube, are being built. Of course, the nearer a chamber approaches a cube in shape, the more absolute chamber room is gained for the lead expended. It is now becoming usual to build chambers of enormous size, with the view of economizing lead. In order that a comparison may be drawn between the old mode of manufacturing sulphuric acid, and the way of proceeding at the present time, some dimensions of chambers at present in work may be given; but it is generally admitted that the best produce is obtained from a series of small chambers, in which one would burn equal to a ton of sulphur *per diem*.

Mr. SCHOLEFIELD, chemical manufacturer, of Bradford, near Manchester, possesses a chamber of the following dimensions—seventy feet long, thirty-five feet wide, and thirty-five feet high; thus possessing the enormous space of eighty-five thousand, seven hundred and fifty cubic feet. The same gentleman has also another large chamber, rather less than this one. It is forty feet long, thirty-five feet wide, and twenty-five feet high. Mr. SPENCE, also, of Newton Heath, alum manufacturer, has a fine chamber of the following dimensions: seventy-five feet long, forty feet wide, and forty feet high; containing, of course, one hundred and twenty thousand cubic feet of internal space.

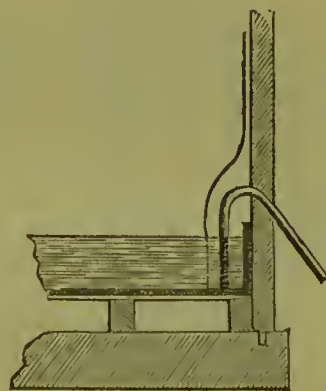
These are not the only ones—chambers of similar

magnificent dimensions are being built in many parts of Lancashire; and at Flint, North Wales, at the gigantic factory of MUSPRATT BROTHERS and HUNTLEY, chambers are of the following dimensions: one hundred and forty feet in length, twenty-four and a half feet wide, and nineteen and a half feet high; the internal space being therefore, sixty-six thousand, eight hundred and eighty-five feet. The above instances are singled out as illustrations of the chambers of the present day.

It will be easily understood that the size of the chamber, or rather the chamber space, must bear some relation to the sulphur burned. Some manufacturers are more successful than others in this respect, being able to produce more vitriol in rather less space than others, probably owing to some variation in working. In a Lancashire work, possessing chamber space to the extent of one hundred and twenty-four thousand, two hundred and sixty-eight cubic feet, they are able to convert eighteen tons of sulphur into sulphuric acid per seven days, the chambers being arranged in the form shown in Fig. 580, to be referred to hereafter. It may be well to notice, that when working with plenty of chamber space less nitre is needed. The reason will be seen when the theory of the action in the chamber has been studied.

As a general illustration of the construction or principle of a sulphuric acid chamber, it may be said to resemble a bell-jar, as used in the ordinary manner for gas experiments. In this case the bottom resembles a large square basin, into which the chamber appears to have been inverted, like the before-mentioned bell-jar in a saucer of water. This is shown in Fig. 578. The height of this basin edge, or turn-up, as it is technically termed, is about twelve inches. Into this, as in the figure, the side dips, and a light water lute joint is produced. By pushing the chamber side a little inwards—as in Fig. 579—from the turn-up,

Fig. 579

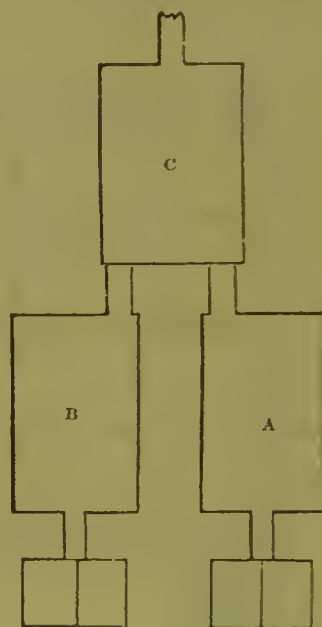


a space is formed in which the shorter leg of a siphon can be put, for the purpose of drawing off the contents of the chamber as wanted.

It is seldom that one single chamber is worked by itself, at any work, unless it be a very small one. The usual plan is to work a greater or less number from one into another. An arrangement is figured in PAYEN'S work, in which some five chambers are represented as forming a battery, the gases proceeding from

one to another through the whole series. But it is not usual to see such a number connected together. In this country, at least, the number is often limited to two or three chambers working into each other. This answers very well. A favorite arrangement is shown in Fig. 580, which represents three chambers connected together. The chamber, A, has one or two

Fig. 580.

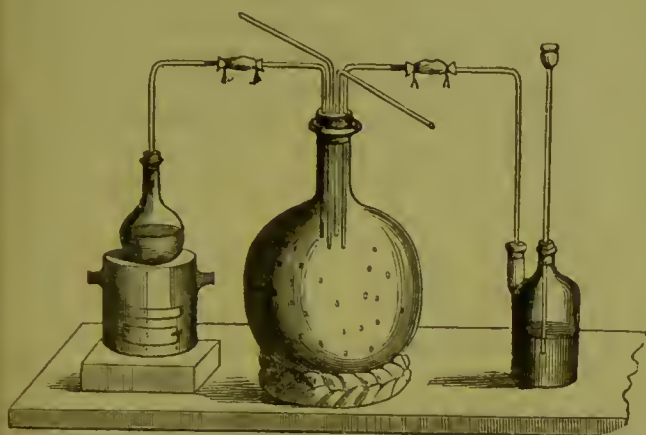


burners attached to it; the same with chamber B. The gases generated in these ovens rise through a cast-iron stalk or chimney into A and B. The portions which escape condensation into these chambers, are conveyed through the passages shown in the drawing into C—the third chamber. If any residue remains it passes with the waste gases into the chimney, through the tube at the end.

Theory of the Production of Sulphuric Acid.—The production of sulphuric acid in the chambers is the result of a series of rather complicated reactions. It was sufficient for the old manufacturers to know, that certain bodies placed in certain relative positions produced sulphuric acid; but for the present day this is not sufficient. The reactions of the different gases and vapors on each other, have been repeatedly studied, and much difference of opinion exists on this head. The reactions are very curious and interesting, the chief being the remarkable and useful property of the nitrous constituent of the chamber gas—of acting as a carrier of oxygen to the sulphurous acid. Were nitric acid capable of yielding up at once the whole of its oxygen to the sulphurous acid, it would require eighty-five parts of nitrate of soda to furnish nitric acid sufficient to oxidize the sulphurous acid produced from eighty parts of sulphur, so as to convert it into sulphuric acid. But in practice one hundred parts of sulphur are converted into sulphuric acid with the aid of from five to ten parts, according to the way of working, of nitrate of soda. This is rather startling; but chemists have traced out the fact, that though atmospheric oxygen is itself incapable of at once combining with sulphurous acid, eventually it is from

this source that the extra oxygen is supplied. The reaction may be studied on the small scale by the aid of the apparatus, Fig. 581, which may for the purpose be considered a sulphuric acid chamber in miniature. This apparatus consists of a large flask or balloon. In

Fig. 581.



this the action is to go on, the flask is to furnish sulphurous acid, while the Woulfe's bottle is for the production of nitric oxide by the action of nitric acid on slips of copper. Tubes from both these pieces of apparatus conduct the respective gases into the large globe, which globe has also two other tubes inserted through its perforated cork—one is for the purpose of introducing atmospheric air, while the other is the exit pipe for the residual gases, *et cetera*. The apparatus is set to work in the following manner:—A small quantity of water is introduced into the large globe. This is turned about until the sides have been wetted. Copper turnings are placed in the two-necked bottle and in the flask, and the whole apparatus is fitted together as shown in the drawing. An ounce or two of strong sulphuric acid is now poured on to the turnings in the flask, and heat applied; as explained under sulphurous acid, this gas begins to be evolved. When a steady stream begins to be given off, a quantity of commercial nitric acid, diluted with about half its bulk of water, is poured into the Woulfe's bottles through the tube funnel with which it is furnished. A stream of nitric oxide— NO_2 —begins to be evolved immediately. This, soon as it comes in contact with the air in the globe, takes up another equivalent of oxygen, becoming peroxide of nitrogen— NO_4 . A reaction now ensues between this and the sulphurous acid from the flask. The NO_4 combines with the SO_2 —sulphurous acid—forming, it is supposed, a compound having the following formula— $\text{NO}_2 \cdot 2 (\text{SO}_3 \cdot 2 \text{HO})$ —water being present; or to follow the decomposition—



This, added to another equivalent of sulphuric acid already formed, the product of a previous action, makes up the formula before given. This latter body makes its appearance as an icy crust on the sides of the globe. Join one of the two open tubes on to a gas holder, or aspirator, and cause a small current of air to be drawn or forced through, to replace the oxygen absorbed by the nitric oxide— NO_2 ; remove this when done, and join on a small retort, or flask containing boiling water;

and now drive a small jet of steam into the balloon. Immediately the steam enters, the frosted coating will melt off the sides and decompose, streams of acid will run down the sides of the globe, and the whole interior will become filled with red fumes. If thought proper, the experiment can be repeated; it is only necessary to throw in a fresh quantity of sulphurous acid. This will again decompose the peroxide of nitrogen, forming the same compound as before—thus the experiment can be gone over several times. In this experiment, it is generally supposed that one has in miniature the action of a chamber; but this is scarcely the exact truth, inasmuch as the circumstances, though very nearly, are not quite the same as on the large scale; and daily experience teaches, that a small difference of circumstances will sometimes produce a great difference in a reaction. In the vitriol chamber itself, all the necessary re-agents are present at the same time, so that it is not unreasonable to suppose that some variation from the above described experiment may take place.

Almost every chemist who has studied the subject, has taken a different view of the question; though all appear to concur in supposing that the formation of the crystalline compound precedes the formation of any sulphuric acid. On this account most ingenious theories have been broached, explanatory of the decomposition which ensues. All concur in the opinion that it is nitric oxide which is evolved when the crystals come in contact with the water. With a view to elucidate the subject, these crystals have been repeatedly analyzed, but the analyses differ much. Dr. THOMSON gave their composition as— $3 \text{SO}_2 + 2 \text{SO}_3 + \text{NO}_5 + \text{HO}$ —a scarcely probable combination. Dr. HENRY again, from his examination, considered them to be composed of— $5 (\text{SO}_3 \cdot \text{NO}_3) + 5 \text{HO}$ —a more likely supposition. The analysis of these crystals must always be a difficult matter. It is impossible to procure them absolutely pure; and even were they obtained pure, they are so very prone to decomposition, that it is almost as difficult to keep them so for the purpose of analysis.

The theory of the chamber reaction just given, and which first originated with CLEMENT and DESORMES, is the one held by many chemists, including KNAPP, who gives it in his *Technology*; but there are others who hold that the decomposition and recomposition of nitric acid is an essential part of the chamber reactions. Amongst these latter may be named PELIGOT, quoted by R. D. THOMSON. PELIGOT considers that there are four phases in the process. The first is the mutual reaction of sulphurous acid and nitric acid, the products being sulphuric acid and peroxide of nitrogen— $\text{SO}_2 + \text{NO}_5 = \text{SO}_3 + \text{NO}_4$. Two equivalents of this NO_4 combine, forming nitric acid and nitrous acid— $2 \text{NO}_4 = \text{NO}_5 + \text{NO}_3$. This nitrous acid again, under the influence of water, is decomposed into nitric acid and binoxide of nitrogen— $3 \text{NO}_3 = \text{NO}_5 + 2 \text{NO}_2$ —which two equivalents of binoxide of nitrogen unite with two equivalents of free oxygen, becoming once more peroxide of nitrogen, which eventually becomes nitric acid by a repetition of the last three decompositions just traced out. The nitric acid formed at these several

stages acts, of course, exactly as in the first instance. Nitric acid is very easily decomposed by sulphurous acid. This may be illustrated by wetting the interior of a bell-jar with nitric acid, then placing it over a capsule of burning sulphur, and setting on a tile or plate; in a few seconds the jar becomes filled with red fumes, the sulphurous acid having abstracted a portion of oxygen from the nitric acid, reducing it to peroxide of nitrogen.

It has thus been attempted to indicate a possible means of one portion of nitric acid or nitrous gas acting *ad infinitum*, converting an almost endless quantity of sulphurous acid into sulphuric acid, without being itself diminished. Notwithstanding the amount of study and labor bestowed on this question, it is doubtful whether chemists have arrived at more than an approximation to the actual reaction in the chamber. When the very changeable nature of all the bodies which there react upon each other is considered, one can scarcely hope to attain the actual truth. The explanations just given of the formation of sulphuric acid, though doubtless such as take place, are probably only two of many; it is likely that a variation in the action of these bodies on each other is perpetually taking place, as there is a deficiency or an excess of nitrous gas, more or less steam, a greater or less quantity of atmospheric air present, a higher or lower temperature, and many other causes may vary these changes; yet one has a tolerably clear view of the general mode of action. It is a general and wide-spread opinion, that the formation of the crystalline body invariably accompanies the formation of sulphuric acid; whereas in practice its appearance is only accidental. That these crystals should be constantly formed under the ordinary working condition of the chamber is almost impossible, when their great instability when in contact with water is considered, and, as in the atmosphere of a chamber properly worked, a great amount of aqueous vapor always exists, their formation is not very probable; for one can scarcely imagine that a body can be produced under such circumstances, that, were the same body ready formed to be so placed, it would be decomposed. Still, these explanations serve to show how it is possible for a small quantity of nitric acid or nitrous gas to convert a large quantity of sulphurous into sulphuric acid, acting as a carrier between the oxygen of the chamber and the sulphurous acid, constantly taking from one and immediately delivering up its plunder to the other. In order to understand the extent of this action, a previous statement must be remembered of the amount of sulphuric acid which a given weight of nitre could produce, were its oxidizing powers limited to the oxygen contained within itself. It is only from this view that the beauty of the chamber reaction is seen; and perhaps no other metamorphosis is, when looked at in a scientific point of view, so beautiful. It is the hinge and turning-point of the whole manufacture; for were it not possible to produce such a large amount of vitriol with the expenditure of such a small quantity of the most expensive ingredient, the commercial value of vitriol would of course be proportionally higher; and as this acid is the starting-point of almost every other chemical salt or body manufactured, these various

salts, *et cetera*, could not be produced nearly so cheaply as at present. As a result of this, the value of all printed and dyed goods would be considerably enhanced, and would be placed out of the reach of many, or at least not easily attained. On the cheapness of this class of articles also, industry in many places depends; so that one may trace much of the trade and prosperity of the country to this beautiful, if not very simple reaction; for though it is possible to produce sulphuric acid without the intervention of nitric acid, none of the methods which have been proposed for the purpose, have gone much further than a laboratory experiment. In a later portion of this article some of these methods will be given.

Having now followed the theory of vitriol-making on an experimental scale, the subject next to be considered is the actual manufacture in the chambers. The construction, *et cetera*, of these, and their various appurtenances, has been already noticed. The chamber arrangement described previously—Fig. 578—has two burners to each chamber; that is, to each of the chambers, A and B. The mode of working these burners is such that a constant stream of gas is sent into the chambers. In order to effect this the burners are charged alternately. Thus, if the two burners attached to a chamber be designated A and B, they are charged at the following hours:—

Burner A.			Burner B.		
Charged at	6 A.M.	....	Charged at	8 A.M.	
"	10 A.M.	....	"	12 noon.	
"	2 P.M.	....	"	4 P.M.	

The same proceedings are gone through with respect to the other two burners. By this mode of charging alternately, it is supposed that as the combustion in one burner loses in intensity the other increases, and *vice versa*; so that a stream of equal volume, or nearly so, is kept up during the whole time.

The burners are charged at the above intervals with a weighed or measured quantity of sulphur. The workman lifts the sliding door, and throws in the charge. Previously to this he inspects the state of the chambers, to enable him to judge what quantity of nitrate of soda he shall decompose simultaneously with the combustion of the sulphur. He puts as much nitre as he thinks necessary into one, two, or more hemispherical iron vessels, or cups, technically termed nitre pots. Immediately he has thrown in the sulphur, he closes the door to prevent the escape of gas; he then proceeds to add to each pot already containing nitre, as much sulphuric acid—from a vessel placed for convenience near the burner—as he considers necessary. This is not a nice or exact operation, the chief point being to add rather an excess of this acid, so as to insure the total decomposition of the salt, leaving a bisulphate of soda, or a mixture of neutral sulphate and bisulphate. When these pots are charged, the door is again opened, and the workman in charge lifts the pots by means of an iron hook, constructed for the purpose, and places them in the burner, in the midst of the now partially ignited sulphur. After a while the sulphur is in a gradually advancing state of thorough combustion, and considerable heat is evolved, which, acting on the nitre pots, causes the complete decomposition of

their contents; the nitric acid is given off, and passes simultaneously with the sulphurous acid into the chamber. A method common on the Continent, but rarely now, if ever, practised here, is the employment of strong liquid nitric acid, contained in basins, and placed inside the chamber at different parts on glass and porcelain triangles. Prefixed to the working chamber is another small one, through which the whole of the sulphurous acid has to pass, while in it are placed a number of earthenware dishes, containing nitric acid. In some instances they are not exactly dishes, but pieces of earthenware apparatus, constructed for the purpose, over which nitric acid is trickled in a slow stream. In either case the object is to expose as large a surface of nitric acid to the action of the sulphurous acid as possible. These two bodies, reacting on each other, produce gases which are carried forward to the working chamber. A rather peculiar arrangement is necessarily employed in order to get the nitric acid into the trays. This consists usually of a number of glass siphons, set into carboys of the nitric acid. These siphons convey the nitric acid into another glass apparatus, of which a bell-jar forms a part; the object of the whole being the conveyance of the nitric acid into the interior of the chamber without allowing any gas to escape. The whole affair is by no means simple, and would scarcely suit the manner of working in this country, as, from its construction, it must be very liable to derangement or destruction. Apart from this, it is not very evident what advantage is to be gained by using the nitric acid arrangement. In the first place, there is all the loss from escape, *et cetera*, incident to the manufacture of nitric acid, as well as the cost for labor, *et cetera*; while, by decomposing the nitrate in the burner, this is economized. Nothing can escape uncondensed, as in making the nitric acid every particle of vapor must pass into the chamber. The combustion of the sulphur affords the necessary heat, while the same labor suffices. On the other hand, it would appear at first sight that by this method the amount of nitrous gas necessary for the chamber could be more nicely regulated; but, on consideration, this advantage appears doubtful, for there would be a difference in the quantity passed through, according as the carboys were full, or otherwise, and the taps could, by a little carelessness of the workman, be left running when there was no occasion for them. Such occurrences have taken place to the destruction of the sides of the chamber.

The only part of the nitre system, if it may be so termed, which appears open to objection, or which may be cavilled at, is the contact of the nitric and sulphurous acids at a high temperature, and in consequence the possible decomposition of the nitric acid either into nitrous oxide or nitrogen, both totally inactive, and for the required purpose wholly useless gases. That such a circumstance has taken place is inferred from a fact which occurred in actual practice. A set of burners were worked to their utmost consumption; they became very hot, and required much more nitrate to keep the chamber in proper working order than previously. It would be difficult, in fact almost impossible, to prove the truth of such an opinion; but, nevertheless, it is

possible, and from the above incident probable; but if, for the sake of argument, the truth of this opinion be admitted, this appears, as far as practice goes, to be the only objection to this method of supplying nitrous gas to the chambers.

A Continental chemist, who employed the nitric acid process, saw the nitre process during a visit to this country, and on his return substituted it for the one he was previously employing; by so doing, he effected a saving of one-third of his nitrate of soda. This result could not have been obtained if there had not been some gross error or carelessness in the mode of working by nitric acid. It is possible that little care was exercised in the manner of working, and that, on employing a fresh process, more attention was directed to the subject; in either case the person was perfectly satisfied with respect to the advantages of working by the English method.

As before stated, however, the heat of the burning sulphur effectually drives off the whole of the nitric acid of the nitrates in the pots, leaving sulphate of soda. The nitric acid as soon as evolved comes in contact with the sulphurous acid from the burning sulphur, and is instantly decomposed by it; often, on looking into the ovens or burners, the whole of the upper portion appears filled with ruddy fumes. These, together with the sulphurous acid, pass up the stalk or chimney which conveys them into the chamber, there to react further upon each other, so as to produce sulphuric acid.

It has been attempted to be shown by the detail of the reactions on a small scale that, theoretically, one portion of nitrous gas is capable of converting sulphurous into sulphuric acid almost indefinitely, were it not that certain practical difficulties intervene; for instance, it must be apparent to the student of these experiments, that although one portion of nitrous gas can go on continually carrying the oxygen of the chamber to the sulphurous acid, yet this action must necessarily stop when the oxygen is exhausted. And this is possible, for were a close chamber taken, containing a limited portion of oxygen with the requisite nitrous gas, and the operator kept on introducing sulphurous acid, it would be found, on testing from time to time, that the quantity of oxygen was slowly diminishing, and that at length it had disappeared altogether.

This could easily have been the case with one of Dr. ROEBUCK's close chambers, worked on the intermittent system. To supply this, it is usual at the present day to admit such a constant current of air, that there is sufficient to supply a stream of oxygen over and above what is requisite for the combustion of the sulphur; this finds its way into the chamber, there to effect the necessary change. This oxygen becomes gradually appropriated by the sulphurous acid, as the current of gas keeps slowly moving towards the exit with a regular and constant motion; and as this appropriation never ceases, necessarily the gases on passing out must get poorer in oxygen in the ratio of their nearness to the exit pipe. And this is found to be the case, for if a portion of the gases from this spot are collected, and the slight amount of sulphurous acid and nitric gases removed, the quantity of oxygen in the residue will be found to be considerably less than in com-

mon air. The quantity found differs even in the same manufactory, as no rule controlling the quantity of air to be admitted exists. In fact, it is considered advantageous to diminish it as much as possible, so as not to take up the space of the chamber with a useless superabundance of air. But whether this is judicious or not is matter of opinion; however, the reader is requested to bear in mind that, as before shown, the nitrous gas reaches the exit pipe unimpaired, and passes out with the residual nitrogen, excess of air, carbonic acid, and other matters. This is particularly mentioned, as this part of the subject will be again referred to, with respect to the method now in pretty general use for the recovery of this nitrous gas, and its replacement in the chambers, in order again to commence its labor. This invention of GAY-LUSSAC's is the only improvement of any consequence which has appeared in connection with the manufacture of sulphuric acid for some years; in fact it leaves little to be desired, except the discovery of a material of which to construct the chambers, which, unlike lead, will be indestructible, or at least unacted upon by any of the bodies to the action of which it will be exposed; although, as will be seen in a later portion of this monograph, this problem has been attempted to be solved, its solution has not as yet been successfully accomplished.

Notwithstanding the number of years that sulphuric acid has been, it may be said, a staple manufacture of England, and so much opportunity has existed for studying this process, much misconception as to the true action of chambers exists. The forms, shapes, and other matters in connection with them which have been proposed and built almost exceeds belief—their name is legion; but the prevailing idea, which appears to have actuated many inventors of these ingenious constructions, appears to have been, that the action of condensation in a chamber was simply that of a distillation process; that as the vapor from a boiling liquid in a still or retort condenses on the cold surface of the worm or other refrigerating apparatus, so with a sulphuric acid chamber, the cold walls condensed the acid vapor contained inside. Evidently, with this idea in view, chambers have been built resembling flues; these, having a large surface of cold lead, were supposed to favor the production of the acid by condensing it immediately on its formation. It is related that a clever chemist across the channel constructed a most novel sulphuric acid apparatus. It consisted of an almost fabulous length of lead tube coiled round and round an apartment like a gigantic still worm; that sulphurous acid and nitrous gas were introduced at the highest end; these reacted on each other, the sulphuric acid when formed passing the whole length of the tube, a constant stream issuing from the other end.

It was not stated what length of time this system continued, but certainly on the face of it not long.

It is no uncommon thing to find long lead flues attached to the chamber, for the purpose of carrying off the residual vapors to the chimney. These flues invariably take a most circuitous course, many times longer than the direct route; and as frequently there is no obstacle or other such reason why the flue should not follow the most direct line, one is inclined to

inquire why this latter course was not adopted. If the question were put, the answer would probably be that a steam jet is introduced at the end of the flue nearest the chamber from which it issues, and that the length of flue, with the aid of the steam, is expected to condense any vapors not condensed in the chambers. If the product dropping out at the end of the flue be examined, it will very probably be found to be so weak as to be scarcely worth the coals required to concentrate it.

Let the true state of the case be examined. Is it absolutely necessary that there should be a surface for condensation? Is this necessary in all cases, natural and otherwise? Does the rain cloud, which, perhaps, in one half hour will come down in the shape of a heavy shower, require a surface for condensation. If it did, possibly rain would be more manageable; but this watery vapor needs no cold surface; it condenses into water, losing the vaporous and assuming the fluid state, without any assisting cold surface. And if the rain cloud be capable of so condensing, is it not possible for the like physical reaction to take place within a vitriol chamber? But further. Is it not probable, or rather certain, that the sulphuric acid in the chambers never was in the state of vapor. Sulphuric acid requires a heat of 620° to convert it into vapor. The highest point of heat a chamber could attain could be no approach to this; probably the heat of a chamber will not exceed 212° in the hottest part where the gas enters. Is it not possible that every atom of sulphuric acid produced passes from sulphurous acid gas to liquid sulphuric acid at once the instant it is formed—that the chamber is filled with myriads of these newly-formed particles—that these float about, and, like globules of running mercury, they gradually coalesce with each other, until they at last form a particle like a rain drop, sufficiently heavy to resist the sweeping influence of the currents which exist in the chamber; and that, finally, this drop falls into the acid on the floor of the chamber. Although it is impossible to see the process, and so prove the truth of this opinion, a very good inference of its justness may be drawn from an experiment which was tried on a chamber. A strip of lead about three inches wide was attached to the inner side of a chamber, in such a manner that it resembled a gutter or spout in an inclined position, one side of this gutter being formed by the chamber side, the other by the strip. This was placed about from two to three feet above the surface of the acid in the chamber, and was about nine feet long. In consequence of this position, the whole of the acid which formed or condensed on that side of the chamber above the strip would flow along it, and be carried by a small tube passing through the wall of the chamber into a vessel placed on the outside to receive it.

If the liquefaction of the acid took place almost wholly on the side of the vitriol chambers, a pretty rapid current of acid must have flowed along this arrangement, but this was not the case; instead of, as might have been expected, a constant stream passing along it, nothing more than isolated drops issued, probably at the rate of six drops per minute, an utterly insignificant quantity, when compared with the amount

of acid which must have been formed within the space over which this strip had the command.

In fact any observant manufacturer must, after a little attention to the subject, come to the conclusion that such is the case; that condensation goes on chiefly within the space of the chamber, although a small portion may condense on the walls; for when the acid particles are floating about in the chamber—driven hither and thither by the various currents which must exist—some must become attached to the sides and flow down into the acid already at the bottom, adding to the amount already formed. But the argument remains that all the acid is not brought to the liquid state by this means; that, in fact, the quantity thus formed bears a very small relation to the whole.

To many this will be already palpable, but evidently not to all, inasmuch as these strange abortions of chambers are not by any means as yet extinct, but still remain a testimony to the ignorance of many of our manufacturers. It must be apparent, that if anything more than the usual average amount escapes from the chambers, either they are badly worked or overworked. If the first should be the case, more attention must be directed to them to find out the error. If the second suggestion be correct, then, as the chambers have more material introduced into them than they can properly work, the amount of sulphur usually burned must be decreased, until the maximum amount which can be burned with a beneficial result is found. It needs little argument to prove, that the working space included in a tunnel could have been included in the chamber at much less expense.

The introduction of steam into the chambers has been already mentioned. Previously to the use of this reagent, the water on the floor of the chamber had all the work to do; every particle of the sulphuric acid and nitrous compound was compelled to pass in to the water from whatever portion of the chamber it was formed in order to be decomposed. The interior of one of Dr. ROEBUCK'S chambers, or any other chamber worked in the same manner, while in action would have been a pretty sight; the reactions must have taken place consecutively, as described in a preceding portion of this article when treating of the theory of the process. Every particle of sulphuric acid formed must previously have passed through the solid crystalline stage. The interior walls of the chamber must have been each time more or less coated and incrustated with the beautiful snow-like crystals, while the whole interior of the chamber must have resembled a snow-storm in an amber-colored atmosphere. The first manufacturer who introduced steam into his chambers did but exchange a beauty he could not see for a solid reality he could well appreciate. He introduced a most beautiful invention, which not only increased the production in the same chamber-space, but altogether simplified the operation. Instead of, as before, each equivalent of the double compound waiting to fall down into the cold liquid which covered the floor of the chamber in order to be decomposed, leaving, probably, a large per centage of the nitrous constituent behind; the bodies now never assume the solid state but on extraordinary occasions, and then only through

neglect. The whole of the reactions take place in a warm wet atmosphere, where everything is favorable to the intended purpose.

Sulphuric acid, when tolerably concentrated, has a tendency to combine with nitrous acid, forming a definite compound to be treated of hereafter; but unless the acid be concentrated, more so, in fact, than it is usually found in chambers, this compound is very unstable in the cold; heat it and the nitrous constituent flies off.

In a chamber worked on the old plan a great quantity of nitrous gas must have remained in the vitriol, causing a great loss of this body—the most expensive material the manufacturer employs. On the contrary, in the chambers of the present day, each particle of acid as formed must, if sufficient steam be present, be of such a density or strength and temperature as to be incapable of carrying down, and thus removing from its proper sphere of action, any of the nitrous bodies present. Again, in the old plan of working, the nitrous gas was only liberated at the surface of the liquid at the bottom of the chamber. Now, peroxide of nitrogen— NO_2 —the body into which the nitrous gas would become changed the moment after its liberation, coming in contact with the oxygen in the chamber, is a heavy gas, heavier than common air. It can be floated about and poured from vessel to vessel like carbonic acid. This then, on its being set free, would float about on the surface of the liquid, running the risk of being rapidly absorbed; whereas its sphere of action lies amongst the lighter sulphurous acid, on the upper portion of the chamber, to which point this NO_2 could only be conveyed by diffusion, or be carried up by getting entangled with the upward stream of gases emanating from the tube which conducts the sulphurous acid into the chamber. In the present system, whenever a particle of this peroxide or quadroxide of nitrogen meets one of sulphurous acid a reaction commences. Now there is no necessity for a descent to the bottom of the chamber; water, in the shape of vapor, pervades every part of the chamber; and as quickly as the crystalline combination forms, if it does form under these circumstances, it is as quickly decomposed. The resulting sulphuric acid falls, but the nitrous gas forms a second combination, and is then again ready to perform its purpose the moment it comes in contact with another particle of sulphurous acid. When carefully considered, it will be understood that it is not too much to call the introduction of steam into the chamber a great invention. It is not difficult to imagine how slow the process must have been in the old chambers when compared with the rate at which it proceeds now, and what enormous advantages manufacturers at the present day are possessed of over their predecessors.

Much difference of opinion exists as to the proper density at which the acid should be kept in the chamber, or rather what is the maximum density to which it may be allowed to rise? All manufacturers are aware that it is to their interest to keep up the strength of the acid in the chamber to the highest point possible, for by so doing there is a saving of fuel in the concentration. A writer has lately stated, on the authority

of an eminent manufacturer, that it is impossible to keep the vitriol free from nitrous gas if a density of 1.45 or 90 degrees. Twaddell is exceeded; while again in KNAPP's *Technology* it is stated, that the maximum density of 1.585, or about 112° Twaddell, should not be exceeded. A considerable margin exists between the two statements, but in such matters as these, which are not found capable of absolute and precise proof, the only course to be pursued is to take for a guide a near approximation to some recognized authority, or perhaps better, to be guided by the result of practice. A set of chambers now at work are kept at a general strength of from 110° to 112° Twaddell. It is not observed that more than a trace of nitrous gas is absorbed, except occasionally, and these instances may invariably be traced to either a slackening or a total cessation of the current of steam, either from the carelessness of the workman or by accident. In either case the pressure of steam has become so low that little or no watery vapor is being thrown in. Perhaps there is no manufacturer who has not at intervals found his chamber acid so highly charged with nitrous gas as to slightly effervesce when poured with violence from one vessel to another; in fact, it is not an extremely rare occurrence, under some circumstances, to find it perfectly green, from holding a large quantity of peroxide of nitrogen in solution. If, when this takes place, strict inquiry be made, it will be found, that such a state of things results from the chamber having been left for some time, possibly for hours, without steam. This point is worthy the manufacturer's attention, as it largely concerns his profits. The chambers, as at present constructed and worked, are not calculated to work on the old plan. As has been stated before, the steam materially quickens the process, and is the means of much more acid being made in a chamber than could be made were it worked on the old plan. When without steam, the excess which the chamber is not able to convert must pass up the chimney, being a loss of its value as well as risk of nuisance or damage. And not only does this occur, but nearly all the nitrous gas which is dissolved in the vitriol flies off when it becomes hot in the concentrating pan, to no purpose but to annoy the workman and surrounding neighborhood. Such a state of things is not an imaginary case, but a fact, as nearly every vitriol-maker can testify, and that to his material cost.

PAYEN gives a method for economizing this nitrous gas passing from the chamber dissolved in the vitriol. This he proposes to do by passing a stream of sulphurous acid over the surface of the vitriol while being concentrated; the sulphurous acid liberates any nitrous gas or decomposes any nitrous compound, and becoming mixed up and absorbed into this sulphurous stream, is carried into the chamber. The apparatus for effecting this purpose, though ingenious, renders the process of concentration too complicated, in fact, leaving a doubt whether the economy effected by its use is not more than balanced by the inconvenience entailed by its employment. Most manufacturers have a very wholesome fear of what is called a break down, and the general want of stability which this apparatus appears to have is not likely to make it a favorite.

The Recovery of the Nitrous Gas.—The reader will no doubt have borne in mind, that whilst tracing out the reaction of the chamber it was possible to follow the sulphurous acid until it was completely converted into sulphuric acid, and that during this process the whole of the free oxygen of the chamber may become exhausted, but that, nevertheless, the nitrous gas still remains the same. This gas does not enter into, neither does it give up, any essential part of itself to the vitriol; its removal is only on account of its passing off with the current of useless nitrogen and other gases, and when removed it still possesses all its active properties, but diluted and incommenced with a quantity of gas of no value. Many have been the attempts to prevent this loss, and to bring the nitrous gas back into a useable form, and this idea has formed the principal feature in many patented improved methods of manufacturing vitriol. Perhaps the most successful worker in this direction was GAY-LUSSAC, the celebrated French chemist. His process, which was patented in this country, is at present in use in several works, and is found to be perfectly practicable, and to answer well the desired end.

In order that the reader may have a clear general idea of the invention, it is necessary to draw on the imagination a little. Let it be supposed possible to construct a filter through which to pass the unaltered air—nitrogen, trace of sulphurous acid, and nitrous gas—which forms the current constantly passing from a chamber; let this filter have the property of retaining the last-mentioned gas, and of letting all the others pass on to the chimney. When sufficient material has been collected on this filter, let it be possible to remove this retained material and to introduce it into the chamber again, there to renew its former labours, and a view is obtained of GAY-LUSSAC's invention. It has been shown that sulphuric acid, when tolerably strong, possesses the power of absorbing, retaining, or uniting with certain of the lower oxides of nitrogen. Most if not all works on chemistry treat more or less of these combinations, although not much appears to be known about them. GAY-LUSSAC studied them to a considerable extent, and perhaps gave the most just account of them; to this study manufacturers are doubtless indebted for the invention. The formulæ of these compounds are given very differently, arising no doubt from the difficulty of separating the different combinations formed, and then of analyzing them. But they appear to be generally considered as compounds of one, two, or more atoms or equivalents of sulphuric acid and nitrous acid, NO_3 . Some view them as compounds of sulphuric acid and peroxide of nitrogen, NO_4 . But whatever the composition, it is certain that peroxide of nitrogen forced into, or rather passed through strong sulphuric acid, is retained by this acid, and the body in question is formed. This is the principle of the process. It may be performed in miniature as follows:—First, fill a potassa bulb apparatus, or a small Woulfe's bottle with strong sulphuric acid—this is for the absorption—connect this with another Woulfe's bottle containing copper turnings; let a safety or tube funnel be put through a cork in the second neck of this bottle, the other neck being con-

needed by a short length of tube with the absorbing bottle, which also must have two orifices, one of which is to receive a short length of tube leading from the bottle just described to the bottom or lower portion of the sulphuric acid. The second neck must be connected with a suitable aspirator gas-holder. When all is complete, pour a little diluted nitric acid through the funnel on to the copper clippings, having previously set the aspirator at work, drawing a stream of air down the funnel and through the sulphuric acid; after a while, when the action appears to diminish in intensity, pour on a little more nitric acid, still keeping the aspirator at work, drawing the whole current of gases through the sulphuric acid. This must be kept on until the sulphuric acid appears to be becoming saturated; this is indicated by red fumes passing through in quantity. The apparatus may now be disconnected. The rationale, which has been partly described before, is simple. The nitric acid acting upon the copper produces nitric oxide, NO_2 . This, immediately on coming in contact with the oxygen of the current of air which is passing through, becomes converted into peroxide of nitrogen, and this is absorbed by the sulphuric acid, forming a compound with nitrous acid, another with nitric acid, being formed at the same time probably as follows:—



In this experiment the imaginary filtration has been really effected. Excess of air, nitrogen, *et cetera*, have passed on while the nitrous compound has been retained; thus one-half the problem is solved. When the apparatus has been disconnected, empty the bulb apparatus or bottle, as the case may be, into a convenient glass vessel, and pour into a beaker glass a volume of hot water, twice the bulk of the nitrous vitriol; pour this nitrous vitriol slowly into this hot water—a copious evolution of nitrous gas will ensue; in fact, if nearly boiling water be employed, almost all the nitrous gas absorbed will be again given off; a small portion will remain, having formed nitric acid as follows, supposing the liquid to be a compound of sulphuric acid and nitrous acid:—



This NO_2 becomes peroxide of nitrogen in contact with the air. The above reaction has been given before in connection with the chamber reaction, but still it is scarcely out of place.

This experiment then is exactly a representation on an experimental scale of GAY-LUSSAC'S invention. Sulphuric acid forms his filter, by which he separates the valuable nitrous gas from its useless companions, although not exactly in the manner just given. Columns for the condensation of gases are well known pieces of apparatus in all chemical works. They are usually tall hollow towers, constructed, according to the purpose for which they are to be used, of stone or lead. They are filled with pieces or lumps of any suitable material which offers a large surface, and at the same time are not acted upon by the acids or acid gases, or other corrosive substances with which they have to come in contact. Coke offers many points of advan-

tage in this particular, as it is acted upon in the cold by scarcely any chemical body; and it offers this additional advantage, that while offering more surface than perhaps any other material at all adapted to the purpose, it is at the same time very light. The column to be employed for the absorption of these nitrous gases is filled with coke, and by means of suitable contrivances, to be detailed hereafter, it is kept constantly moistened with a small stream of strong sulphuric acid, which is continually run on to it. The gases from the chambers are made to pass up or through this column or tower on their way to the chimney; and in order to do so, they have to wend their way through the many thousand passages and openings formed by the interstices existing between the pieces of coke. Thus they are split up into numerous streams, and have to come in contact with many hundreds of feet of surface wet with vitriol before they arrive at the exit pipe. The apparatus is built of such size and proportion that the gases in their course upward are brought into contact with sufficient sulphuric acid to absorb the whole of the nitrous gas contained in them. The acid containing the absorbed gas is collected in a proper reservoir or receiver, placed at the bottom of the column for its reception, from thence, as will be seen hereafter, to be removed, in order that it may be decomposed in such a manner that its nitrous constituents may be again used.

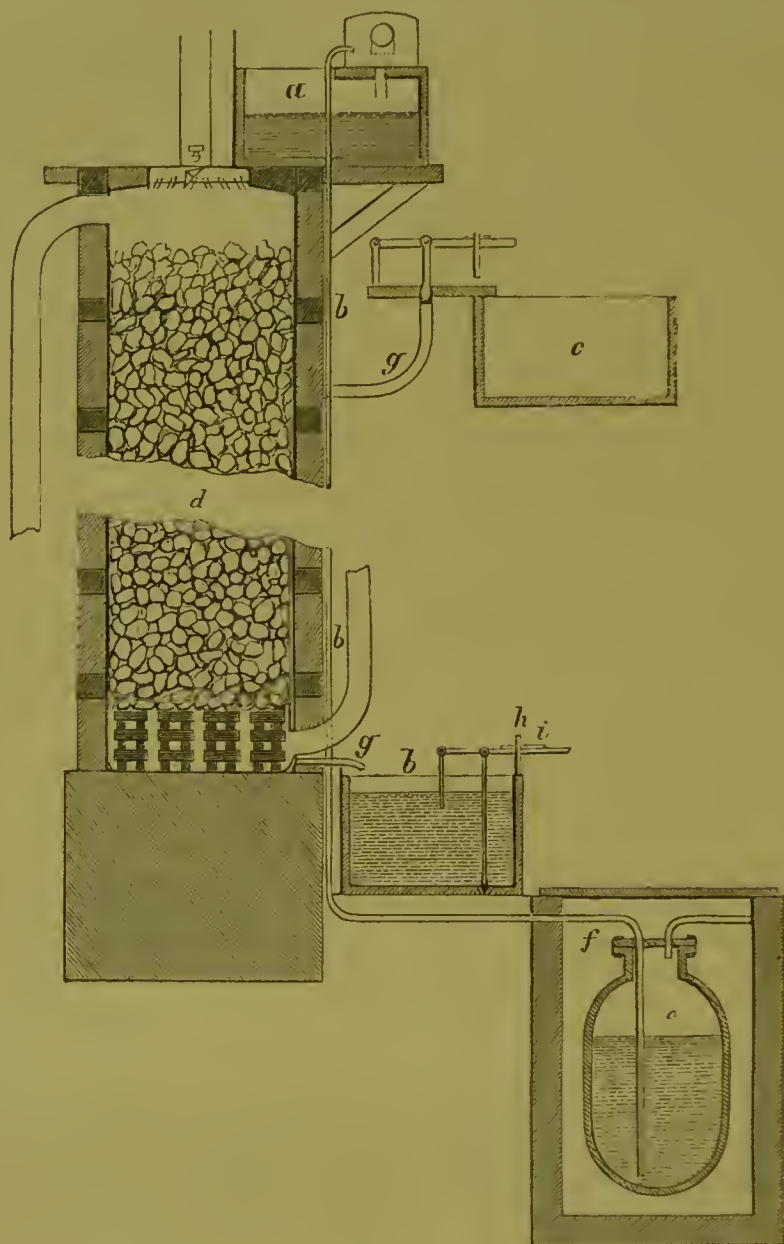
This apparatus seldom or never works well when applied on the small scale, as, for instance, when applied to one or two small chambers. This is a practical difficulty which, perhaps, in the hands of a careful and determined person, might be got over. It has been applied on a small scale at several works, and has been given up. On the other hand, several vitriol manufacturers on a large scale who use it, speak very satisfactorily of its performance. In some cases, by its employment, the consumption of nitrate of soda has been reduced from one-tenth the weight of the sulphur employed to one-twentieth—in fact, to the extent of one-half of that previously used. This is certainly a very good result.

The dimensions here given are those of an apparatus which is applied to a set of chambers, in which an average of eighteen tons of sulphur are consumed or converted into sulphuric acid per week of seven days. The apparatus is seen in Fig. 582. It consists essentially of the column or tower itself, three cisterns for holding or containing vitriol—*a*, *b*, and *c*—together with a large close cast-iron cylinder, *d*, employed in raising the vitriol to be used for absorption from the surface to the upper cistern at the top of the column, and also for removing this when nitrated or saturated with nitrous gas. The tower cannot be more appropriately described than as a tall cylinder of lead, five feet diameter, and thirty feet high, supported, like the lead of the chamber, by a suitable strong wooden framework. This leaden cylinder is completely closed in at the top, and stands in a suitable leaden dish or tray at the bottom, of such a depth that it always contains vitriol enough to lute it, and so prevent any escape of gas. The thickness of the lead is from a quarter to half an inch—some manufacturers preferring to use the thinner variety from motives of economy, while others, in order

to insure absolute safety, prefer to use half-inch lead. This cylinder, as stated before, and as shown in the drawing, is filled almost completely with large pieces

of coke. The quality of this coke is not by any means a matter of indifference: it must be in large firm pieces, for if it is either in small pieces of a rotten or soft

Fig. 562.



variety, it must be rejected; for, if small, sufficient space will not be left between the pieces for the proper passage of the gas, but will choke up the whole apparatus: besides the weight of the coke in the upper portion of the column will crush that near the bottom, and a similar result will follow. It will be, perhaps, well to mention, that if quarter-inch lead is used in the construction of the column, it would be well to line it with thin fire-tiles. These must be applied simultaneously with the filling in of the coke, as it would be impossible to hold them in their places otherwise; they must be placed as close as possible to the lead, and pressed to it, and held in their places by the coke pressing against them. This precaution of brick lining is necessary to prevent—what might otherwise occur—the cutting of the lead by the sharp edges of the coke; for although the column may be quite full at the first, yet, after a while, it will be seen that the whole mass

has subsided some inches, has in fact settled down, and were the tiles not in their places to protect it, it is possible that a sharp edge of coke might cut a slit in the lead.

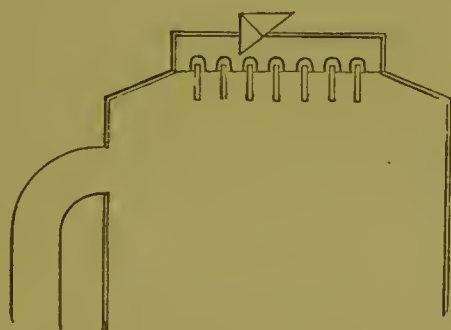
It is necessary to have some arrangement at the bottom of the column by which the gases from the chamber can have unobstructed entrance, for were the coke at once thrown in, without some contrivance for this purpose, it would fill up the entrance pipe, and prevent or nearly so, the entrance of the gases. A very good arrangement for this purpose may be made with fire bricks, which are almost unacted upon by acids. The lower part of the tower or column, to a few inches above the entrance for the gases, is filled in with these fire bricks—arranged in a systematic manner; in fact, built up in the most open and loose manner possible, so as to allow the greatest amount of inlet to the gases. The coke is piled above this. By this arrange-

ment the gases have all but a totally uninterrupted entrance; they rush up through the wide spaces left by the brick, and from thence divide themselves amongst the numerous passages which they find between the coke.

At the top of the column is placed the eistern containing the vitriol, which is run down it. Care should be taken, in the construction of an apparatus of this kind, that the timber work is sufficiently strong to bear the rather heavy weight of this eistern; but this, of course, is what few would overlook. Inserted into what may be called the roof of the column is a device for spreading the vitriol over the whole surface of the coke. In fact a good deal depends upon this, for were the vitriol run on just in one spot, it might possibly find its way down in one small stream not capable of taking up the nitrous gas, in consequence of its having little surface. KNAPP recommends this spreading to be effected by a series of cones placed within each other; these cones, which, as might be supposed, are constructed of lead, have each the apex removed, and the open ends of the whole system are placed immediately under an orifice in the roof of the column. The vitriol is made to enter these open ends in flushes; it rushes over the surface of the different cones, and finds its way to the interior, wetting the coke with a series of concentric circles of sulphuric rain. This will be understood by referring to Fig. 581.

A method which answers tolerably well is shown in Fig. 583. This is an arrangement actually in use. It will be better understood by supposing a broad flat dish, about two-thirds the diameter of the column

Fig. 583.



itself, to be placed on the roof of the column. Into this are inserted a number of tubes—about twenty or thereabouts; these tubes protrude both down into the column, and for a shorter distance up into the dish. The under portion of the tube can be bent, so that the stream which it delivers can be directed to any point desired; for instance, let the whole area of the column be mapped out, and twenty different equi-distant spots be marked; a tube is directed over each of these spots, so that when in action the coke is wetted in twenty different places, in this way increasing the chances of the whole body of it getting thoroughly moistened. Whatever mode of attaining this end may be adopted, the use of an oscillating box, or what the workmen, perhaps more expressively than elegantly, term a *tumbling box*, is almost absolutely requisite; for, in the

last-described scheme, without such an adjunct the spreading would be very inefficiently performed. The stream of vitriol which is run down a column of this description is, comparatively speaking, very small; and when this comes to be divided into twenty separate streams, they must naturally become very much less; so much so, in fact, that the chances are, that unless the ends of the tubes which project into the basin are exactly of one level, which practically is impossible, some three or four which happen to be the shortest, will take almost the whole of the stream. This casualty is put out of the question by the use of the oscillating box, the action of which is to deliver a comparatively large body of fluid at intervals, and this from a small stream. It is easy to see that each time the box oscillates and delivers, say a quart of fluid, the height of the liquid in the basin suddenly rises, and then immediately subsides, enough fluid having been delivered to furnish a current for each of the twenty different tubes.

It would, perhaps, be well here to describe the construction of one of these oscillating boxes, notwithstanding their being well known, and their action thoroughly understood. It is an old invention, and has been figured and described in many works on chemistry. It is constructed of a shape similar to that of two cones fastened together at the base and sectioned, with an axis connecting the apices; this will be seen by referring to Fig. 584. This apparatus, as depicted, is a diamond-shaped box, open at the two upper, and closed at the two lower sides. The box is divided into two by a partition, *a*, in the centre, and the whole is mounted on an axis, *b*, on which it can oscillate. It works, in this manner, one of the two spaces caused by the division, presents itself to the tap of the eistern, or other vessel, whence a small stream is issuing. It will be seen, by examining the figure, that the fuller one of these spaces becomes, the more to that side must the centre of gravity incline, until at length this centre of gravity gets thrown so far beyond the axis, as to overbalance the empty side of the box. When this occurs, the whole of the liquid which this division contained is emptied out suddenly, and the other side presents itself for filling; the apparatus taking the position indicated by the dotted lines. Of course, in a short time, this side becomes full, when a reverse again occurs, and so on as long as there is sufficient liquid to keep it in motion.

Fig. 584.



Another point of some importance in connection with the economizing powers of this column, is the regularity of the stream of acid which runs down. If the tap of the eistern, whence the acid flows, is set to a certain speed at the commencement of the space of time during which the acid is to last, it is certain that it will not run at the same velocity when the eistern is getting nearly empty; nor, according to the proper physical law which controls these matters, will it run with the same force during any two portions of time. According to the law, the rate decreases as the square root of the depth; or, to take a practical and easily understood illustration—suppose it is a cistern three feet deep, then whatever the

number of quarts, gallons, or other volumes per minute at which it runs, it will be delivering exactly half that number when the cistern has lowered to nine inches deep. Thus at one time there would be running down exactly half the quantity as at another; at one period probably supplying the apparatus with more vitriol than is necessary to take up the nitrous vapors, and at another time not giving it sufficient acid, thus allowing a valuable substance to escape.

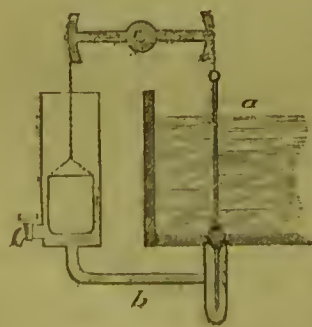
This idea appears to have struck either the original inventor, or an early employer of this process; for in KNAPP'S *Technology*—which appears to be the only book in which a description of this process is inserted—a drawing of a method of obviating the defect is given. It is there proposed to employ a closed cistern, in principle resembling a bird's drinking fountain, where water can only be obtained by replacing the space occupied by it with air; and to cover this cistern with a top constructed of thick lead, supported in the interior by iron rods, sheathed in lead, to protect them from the action of the acid. When working, this apparatus must have had two alternate currents passing through the tap, one current of air into the receiver, to supply the place of the acid flowing out of it into the oscillator.

Several objections to this plan present themselves. In the first place, such a closed cistern must have been very inconvenient to work, in consequence of the increased amount of manipulation; for it was necessary to have an orifice in the cover through which to fill it. This aperture required to be made perfectly air-tight when the cistern was filled; for if this was not done, the whole principle involved became nugatory. Again, the construction of such a receiver must have presented many difficulties, not to speak of the great liability to leakage in the cover and other parts of the cistern. Besides, when the cistern leaked, a great portion of the cover would require to be removed, in order to admit a workman to repair it; the cover itself would also have to be repaired, taking up much time, during which the whole apparatus would be inoperative.

Many other objections present themselves on examination, but are scarcely worthy of remark, inasmuch as no cistern of this construction appears to be at work at this time, at least in this country.

An apparatus which answers the desired end very

Fig. 585.



well has been applied; and it has none of the objectionable features just described; it is shown in section in Fig. 585, where *a* represents the cistern containing the supply of acid. Adjoining this cistern is a circular vessel of lead, twelve inches in diameter, and of the same height as the cistern. Between these two, and from the bottom of each pro-

ceeds a tube, *b*, which forms a passage between them. This tube is not a whole piece of tube, neither does it take the shortest course between the two vessels, and

this for a reason which will be presently shown. The upper portion of the pipe opening into the cistern is of a conical shape, and into this is fitted a conical lead plug, which has been cast on a long iron rod, and turned up in a lathe very smoothly and with great nicety, so as to fit very accurately into its seat, the conical mouth of the tube just mentioned. This plug, as shown in the drawing, has the iron rod, which forms its stem, prolonged below the plug proper some eight or ten inches. This portion, as well as the upper, up to within an inch or two of the hook at the top, is coated with lead. This coating must be done very accurately, to insure the exclusion of the acid from the iron rod. This is best done by pushing the rod through a lead tube of the proper diameter, and fusing the extremities of the upper and lower portion to the plug proper by means of the blowpipe jet, described in that portion of this article which treats of the construction of the chambers. The lower length of the rod moves in the straight portion of the tube below the cistern, and is for the purpose of preventing the plug getting out of its seat, as well as for accurately guiding it in.

Within the tall cylinder before spoken of hangs a leaden bucket, for so it may be most appropriately called; the rim, or upper edge of this bucket, has an iron ring inserted into it, for the purpose of keeping it in its proper shape. To this ring are attached three iron chains, not unlike, in thickness and general appearance, to dog-chains. These chains are attached at a short distance to a single chain, which hangs in the centre of the cylinder. The upper end of this chain is in its turn attached to one end of a lever, moving freely on its axis, situated at the middle of its length. To the other end of the lever is attached another short length of chain, connecting the end of the lever with the hook at the extremity of the plug. This lever has semicircular pieces of iron attached to its ends, over or on which the chains rest, in such a manner that the plug and bucket have each, as near as may be, a true vertical motion, so that the plug may descend exactly into its seat, and that the bucket may move up and down precisely in the centre of the cylindrical vessel. This cylindrical vessel has the delivery tube fastened to it, and the tap from which the stream flows attached to it again.

In order to work effectually, imagine that the apparatus is newly attached, and has not been used before, and that this is the first trial. Let one imagine that the plug has been inserted unattached to anything else into its seat, and also that the cistern is full of vitriol; also determine that the vitriol shall run out at a pressure of some six or eight inches—vitriol pressure, not water. To do this, let the bucket hang down in the cylinder some six or eight inches from the bottom; attach the chain to the lever, and then attach the plug by means of the chain to its other end. In both cases this should be done so that the lever remains in a horizontal position; then let the bucket fall to the bottom. The result of this will be that the plug will be drawn from its seat, and the vitriol will run from the cistern into the cylindrical vessel through the communicating pipe. Now, watch

the action of the apparatus as the vitriol rises in the cylinder. As it does so the bucket will rise. Now, as first said, this bucket is fastened to one end of the lever, while the plug is fastened to the other—in point of weight the plug is the heaviest. Under these circumstances it naturally follows, that as the bucket ascends the plug descends, until at last the bucket ascends so high that the plug falls into its seat, and effectually closes the passage. If allowed to remain, and if the plug fits well, the liquid rises no higher in the cylindrical vessel. But if the delivery tap be opened the liquid in the cylinder will be seen to subside, the bucket descend, and the plug be lifted from its seat so high that it allows just so much liquid to pass it as is running out through the tap, whatever this quantity may be.

Thus, on examining the action of this apparatus, it will be found that it allows the cistern to be run almost empty at precisely one pressure, either six, eight, or any number of inches, thus obviating the misjudgment of the workman, or, what is probably oftener the case, the total neglect of its rate of running. A careful workman, from constant practice, soon learns to set the tap so that it shall run many hours without altering; he has only to notice the time required to run so many inches out of the cistern, it having a gauge with inches marked on it for this purpose; from this he can easily calculate, from the depth of the cistern, whether it will last out the required length of time. If the rate of running is not correct, it must be altered less or more accordingly. As this apparatus is not patented, it may probably find other applications.

Having now described the mode of running the acid down the column, let attention be turned to another and previous portion of the subject—the manner of placing it in the cistern. It is well known, and is a matter of no little regret, that as yet there is no real acid pump. Weak vitriol can be pumped with a pump of the ordinary description—the barrel formed of lead, the valves and all the flexible portions being formed of caoutchouc. But this latter body, and every other body which serves its purpose for ordinary liquids, is destroyed in a few hours, when placed in strong sulphuric acid even when cold. Such being the case, another contrivance is adopted—a very useful although not a very new one, it being at least as old as the chemist's eductor, used in analysis for washing precipitates. This apparatus, as is well known, enables one to drive out a rather forcible though small current of water by atmospheric pressure applied on the surface of the water contained in the bottle. This is effected by closing the neck of the flask or bottle employed with a cork through which two tubes pass, one of which descends to the bottom of the flask below the surface of the contained water, while the other merely protrudes below the bottom surface of the cork. By means of the mouth, air is forcibly compressed within the bottle; this, in its efforts to escape, drives the water before it in a stream; and this is the principle of the apparatus by which the vitriol is elevated. A large cast-iron vessel, *e*—Fig. 582—replaces or rather represents the washing bottle. This vessel is for con-

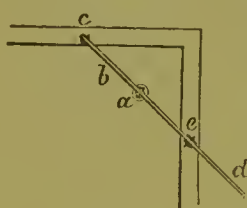
venience placed in a walled cell or space dug in the ground, and is made of such dimensions that it will hold rather more than the cistern it is destined to fill. It is formed not unlike a soda water bottle, this shape being the strongest, the lower and upper ends being rounded, the latter having a flanged neck cast upon it; this being about one foot wide. This flange has a number of bolt holes cast in it, corresponding to a like number of bolt holes in the lid. The lid has two perforations cast in it through which two two-inch diameter pipes can be passed and be secured, one of which pipes, as in the case of the wash-bottles, passes to the bottom, or nearly so, leaving a space of merely two or three inches; the other pipe merely passes through, terminating beneath the lid. Perhaps the best method of making a secure joint between this lid and the vessel flange is to insert an India rubber ring of such a size that it will lie within the circle of bolts; the ring being thus placed, the bolts are put in and screwed up tightly, thus compressing the elastic washer, and forcing it to fill up every crevice, so as to be effectually air-tight. The whole of this description will appear much clearer on referring to the figure—Fig. 582.

The drawing which accompanies this is scarcely complete, inasmuch as one cistern has been left out; this has been done purposely, so as not needlessly to complicate the figure. In order to explain the drawing the reader must consider himself working the apparatus. In the first place, suppose the iron cistern, *e*—Fig. 582—to be filled with vitriol of the density 1.750, or 150° Twaddell, this being the strength of vitriol to be used in the absorption of nitrous gas. At this moment it does not matter how it was filled. By means of a powerful air-pump, a strong pressure of air is forced on to the surface of this vitriol, driving or forcing it up the pipe, *f*, into the cistern, *a*, which it fills. From this cistern it runs, as has been already described, into the column, where, after traversing the coke with which it is filled, it runs into the dish-like vessel in which the column may be said to stand. From this it runs by means of the pipe, *g*, into the cistern, *b*; it is now by this time saturated, or nearly so, with nitrous gas, which it has gathered during its passage down the tower. From this cistern, *b*, it is once more run into the iron underground vessel; the air-pump is once more put into requisition, and it is forced from this vessel into the cistern, *c*, there to be reserved and run off as wanted, to be decomposed in the chamber.

As before stated, the cistern for the raw vitriol is not included in the drawing, but, as it is only a copy of the one at the foot of the column which is represented, a description of the one will serve for the other; it will also suffice to describe how the nitrous vitriol is conveyed from the cistern, *b*, into the cistern, *c*. It will be seen that from the bottom of the cistern, *b*, a short tube proceeds, which immediately joins on to the main pipe or artery, *f*; into the conical mouth of this pipe which opens into the cistern, a plug is fixed, which plug, like the one already described, is simply a conical boss or mass of lead cast on to the end of a sufficiently long rod of iron, and turned in a lathe to a fine surface, so as to make as accurate a fit as possible, the shank being sheathed in lead so as to

preserve it. The upper end of this rod is split, so as to embrace a lever, to which it is firmly attached by a hinge-like joint. This will be better understood by referring to Fig. 586, where *a* is the plug, as already described; *b* is the lever to which it is attached; *c* is a joint at one end of the lever, and which serves as a fulcrum; *d* is the handle at the other end of the lever; *e* is a guide in which it works, and which confines its movements to a simple vertical motion. The plug apparatus is fixed, as shown in Fig. 586, across the corner of the cistern. Now, to get the vitriol in *b*—Fig. 582—into the iron vessel, the workman simply

Fig. 586.



lifts the plug at the corner of the cistern; this he does by a sudden jerk, after loosening a little piece of apparatus, to be hereafter described, and which is for the purpose of keeping the plug in its place and preventing its rising when the pressure comes on to its under surface. Immediately he lifts

this plug the sulphuric acid proceeds to run down this short tube into the main artery, and thence into the cylinder, driving out the air through a tap placed for the purpose. Immediately the cistern is empty, the workman by a forcible thrust fixes the plug in its seat, and for fear the pressure should force it out, he proceeds to fasten it down, as shown at the cistern, *b*—in Fig. 582—where in the upright, *h*, a number of holes are shown; into one of these a cotter, or piece of round rod iron, is thrust; then between this cotter and the lever he drives in the wedge, *i*, thus effectually preventing the rise of the lever, and consequently firmly holding the plug in its place. As soon as this is accomplished, he proceeds to set the air-pump in action, which air-pump injects air on to the surface of the vitriol; and when sufficient pressure has accumulated, the acid gradually flows along the horizontal pipe and main artery, *f*, until it arrives at the pipe, *f*, along which it proceeds, eventually emptying itself into the cistern, *e*, the air-pump being kept in action until all the vitriol is forced out of the cylinder, and a small portion of air following indicates when this has taken place.

The next part of the process is the conveyance of raw vitriol into the cistern, *e*. The details are precisely similar to those already described. Let the reader imagine another cistern precisely like cistern *b*, a perfect copy plug included, which said cistern has a short plug connecting it with the main pipe or artery, *f*. As in the case of cistern *b*, the workman removes the plug, and allows the vitriol to flow into the iron cylinder as before; when he has done this he proceeds to take measures for projecting this charge into the cistern, *a*, at the top of the column.

On the branch pipe leading to the nitrous vitriol reserve cistern, *e*, a plug apparatus will be observed. This is for the purpose of closing this branch pipe while raising the raw vitriol, and is taken out when the nitrous vitriol is being pumped up. It is scarcely necessary to remark that when the nitrous vitriol flows through this branch pipe, it naturally issues at the open end over the cistern, *e*, such being the lowest. In order to prevent

the raw vitriol taking the same course, the workman firmly inserts and fastens down this plug, and, when the acid to be used for absorption has filled the iron vessel, he sets the air-pump in motion, and the vitriol runs up to and flows into cistern *a*.

In consequence of the height of the column of liquid rising from the bottom of the iron vessel to the upper edge of the cistern, *a*—a space of nearly thirty-eight feet—and of its superior gravity, a pressure is exerted approaching to thirty pounds on the square inch. Hence it will be apparent that the cylinder and its appendages must possess a considerable amount of strength. It is usual to have them cast two inches thick in the sides in order to withstand this weight.

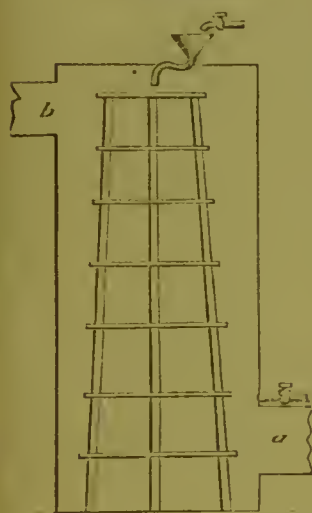
The air-pump used in this case, and which has been so often mentioned, is constructed on the model of an iron furnace-blowing engine, and differs from it only in dimension. The cylinder of this pump may be about eight inches diameter, the length of stroke being twelve inches, and it makes about fifty strokes per minute. It has a rather heavy fly wheel attached to it, to steady its action. This is necessary on account of the great resistance it has to overcome at the end of each stroke. It is necessary that the piston should fit very accurately, and that about the pump and the fittings generally great care should be taken to insure perfect freedom from leakage.

The quantity of sulphuric acid used in the absorption is rather variable, some manufacturers being more successful in this respect than others. Many who employ this apparatus recommend one-third of the make to be run down every twenty-four hours. In this case, for every hundred tons of acid made per week, nearly five tons would be run down per diem. One manufacturer finds in practice that about four hundred gallons, or seven thousand pounds, run down the column every twelve hours, will absorb the nitrous gas from a set of chambers which are converting eighteen tons of sulphur weekly into sulphuric acid.

To utilize the nitrous vitriol it is necessary to liberate the nitrous acid it holds, either within the chamber or contiguous to it, and in presence of the sulphurous and other gases entering it. Simple dilution with water effects this, as explained at page 1033. Still its practical working at first was found somewhat difficult, and much ingenuity has been expended in improving this part of the process, but still something further remains to be done before it can be considered perfect. The original inventor gave a method which, though theoretically almost perfect, was, unfortunately, not quite so, practically. It consisted in exposing the nitrous sulphuric acid in thin films or sheets to the action of the sulphurous acid which issued from the sulphur ovens. By this he proposed to liberate the nitrous gas, and in part he did so. The apparatus is shown in Fig. 587, which represents a sort of leaden column. Within this column a series of horizontal shelves or partitions are placed, which almost fill up the whole of the area; a funnel, furnished with an S tube, is inserted into the roof, and through this the nitrous sulphuric acid is poured on to the shelf immediately beneath. It runs from this first shelf on to the next one, and so it proceeds to the bottom, in exactly an opposite direction to that

pursued by the sulphurous acid current, fresh portions of which it meets at every point of its progress downwards. The funnel tube is of an S form, for the purpose of preventing any of the gas escaping, a quantity of the liquid being retained in the curvature of the tube sufficient to prevent effectually the loss of any gas.

Fig. 587.



The sulphurous acid is admitted into this column through the wide tube at *a*, while immediately above this a jet of steam is thrown in; these together, after traversing the spaces between the shelves and acting on the downward stream, finally escape laden with nitrous gas into the chamber through the passage, *b*.

The jet of steam just mentioned is for the purpose of diluting the nitrous sulphuric acid, and so causing it to yield up more readily the nitrous gas.

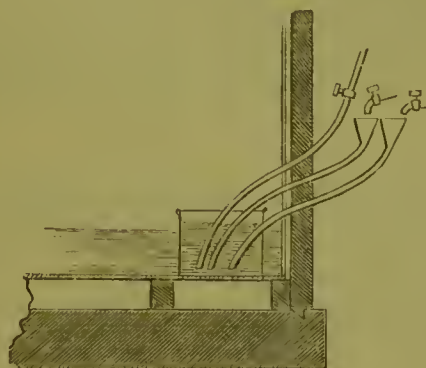
The acid, by the time it reaches the bottom, is supposed to be thoroughly denitrated, and is conducted thence to an evaporating pan to be concentrated, in order that it may be once more used for the absorption of a fresh portion of gas in the absorbing column. Theoretically considered, the nitrous vitriol ought to run from the lower portion of the apparatus without containing more than a trace of any nitrous body. On the contrary, it might be expected to be charged with sulphurous acid, but practically this does not appear to have been the case; for, from the statement of those who had ample opportunity of examining its action, it appears that the nitrous constituent was never thoroughly eliminated, that it still retained a considerable quantity of this gas after very slowly traversing the apparatus, and that this impossibility of thoroughly decomposing the compound acted as a strong barrier to the introduction of the invention. But, happily, this defect was not unconquerable, and was, by a reasonable amount of skill and patience, eventually obviated, at least practically so, if not perfectly.

The nitrous sulphuric acid is decomposed, but comparatively slowly, when subjected to the action of sulphurous acid in an undiluted state; and this appears to have been the cause of the failure in the commencement, inasmuch as the acid flowed from the decomposer almost of the same density as when introduced. It would seem inconsistent that the expedient of mixing it with water so as to dilute it was not adopted, especially as the decomposing action of water *per se* must have been observed. Doubtless this would have solved the problem, especially as with this addition a modification of his apparatus answers very well.

The mere dilution of this nitrous sulphuric acid with hot water answers very well. This is done within the chamber. A section of the apparatus employed is shown in Fig. 588. It consists in simply placing within

the chamber, and as near the burner stalk as possible, a round leaden vessel about twelve inches high and eighteen inches diameter. This is placed close to the

Fig. 588.



leaden wall of the chamber. This leaden wall is pierced by three tubes, all terminating within the leaden vessel, and near to its bottom. One of these tubes conveys the nitrous sulphuric acid into the vessel; the second conveys water; and the third is a steam-pipe. The two tubes for the liquids terminate on the outside of the chamber in funnels, while above these funnels are the respective taps, one of which communicates with the nitrous vitriol-store cistern, and the other with the supply of water. The steam-pipe is, of course, in connection with a generator.

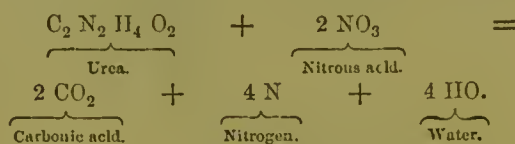
Supposing the chamber to be at work, the mode of operating, with this arrangement, is very simple. The leaden box or vessel is first run full of water—this is by means of the steam jet brought to boiling. The operator or workman then proceeds to run in a slow stream of nitrous vitriol and water from their respective taps. Immediately the nitrous vitriol touches the hot water below, it decomposes into sulphuric acid simply,—which remains in the vessel for a while—and nitrous gas, which flies off, and which is, by the current of gas ascending from the burner, carried off, and enters into the working of the chamber.

Of course, the vessel always remains as near as possible full. The streams of fresh liquid running in immediately displace and drive out a portion of the previous contents, causing it to mix with that already contained in the chamber.

There are at least two advantages which arise from placing this decomposer as near the burner-pipe or gas tubes as possible. In the first place, the gas arising from the decomposition has a better chance of thoroughly mixing with the rest of the gases which form the chamber mixture; and, in the next place, this rapid removal and immediate mixture lessens the risk of local action on the chamber, nitrous gas being rather destructive to lead. In fact, the rapid current of sulphurous acid gas must sweep away every particle of nitrous gas as fast as it is liberated. One of these decomposers has been working in a chamber for nearly three years, and the lead in its immediate neighborhood does not appear to have suffered more than that in any other part of the chamber.

Mr. PETER HART of Manchester has given a method of estimating the value of this nitrous vitriol

by a process of analysis by which one may, in a very simple manner, determine how much nitrate of soda or nitric acid a given volume of this nitrous vitriol represents, or is equal to. The process is founded on the well known reaction which takes place on bringing nitrous acid and urea together, the result of this proceeding being the formation of water, nitrogen, and carbonic acid gases, as shown in the following formulæ—



Mr. HART prefers to employ urea, in the shape of nitrate, on account of the facility with which it can be obtained pure. Of this nitrate of urea he weighs out twenty grains, and dissolves this in about two and a half ounces of water, heating this solution to boiling over a gas lamp. Meanwhile he prepares a test liquid, composed of thin starch water, in which he dissolves a small quantity of iodide of potassium. He spots a white plate with drops of this liquid. He then fills up an ordinary alkalimeter with the nitrous vitriol to be tested. Meanwhile the solution of urea has arrived at boiling, at which point he lowers the gas flame, and proceeds to add the nitrous vitriol from the alkalimeter to the solution in the basin. The reaction goes forward with strong effervescence, and escape of nitrogen and carbonic acid gases. He continues to add the nitrous vitriol drop by drop, not neglecting to stir until a drop, taken out of the basin by means of a glass rod, and added to one of the test spots on the plate, causes the latter to assume a blue color. This indicates the completion of the operation. The number of measures used or added are read off, and this forms the data for the calculation. The rationale of the process is very simple. After the decomposition of all the urea, the nitrous acid, which hitherto has been simultaneously decomposed with the urea, now remains in a free state. Now, it is well known that nitrous acid decomposes hydriodic acid, setting iodine free, which iodine will immediately combine with starch, if any be present. This is one of the tests for nitrous acid; so in this case the formation of the blue coloration indicates free nitrous acid in the basin; and free nitrous acid present indicates the decomposition of all the urea.

The calculation is based on the fact, that to decompose the twenty grains of nitrate of urea employed, there would be required 12.35 grains nitrous acid, NO_3 , which is equivalent to, or represents in chamber effect, 17.56 grains nitric acid, NO_5 , or 27.64 grains nitrate of soda; consequently the number of alkalimeter measures of the nitrous vitriol required in the decomposition represents or contains the equivalent of any of these numbers. All that remains to be done is, to ascertain the relation borne by this quantity to the volume which the cistern is capable of holding, or contains at the time of the experiment; or to put it as Mr. HART gives it—let a represent the number of alkalimeter measures employed of the nitrous vitriol; b the nitrate of soda—if the result is required in nitrate of soda—corresponding to the twenty grains of nitrate of urea, as given above; c the number of alkalimeter measures in a gallon—

seven thousand—and d the number of gallons in the cistern; then—

$$\frac{b \times c}{a} \times d = x$$

x indicating the equivalent in nitrate of soda of the recovered nitrous acid in the entire cistern.

Another method of recovering the nitrous gas has been lately patented in this country. It differs very considerably from the one already described, that is, in principle, although the apparatus bears a great resemblance. It consists essentially in converting the nitrous gases into nitric acid, and combining this acid with lime. The inventor starts out with a column, as in the last process, filled with suitable materials to afford a large surface, down which he runs a stream of thin milk of lime, allowing the waste gases from the chamber to ascend in the opposite direction. In this case it is supposed that, under the influence of the alkaline fluid and excess of atmospheric oxygen, the oxides of nitrogen will be wholly converted into nitric acid, which will immediately combine with the lime, forming nitrate of lime.

It is well known that nitric acid can be reproduced from any of the lower oxides of nitrogen—with the exception of, perhaps, the lowest, nitrous oxide, NO , when in contact with water and free oxygen. This has been dilated upon, and the reaction given when treating of the chamber reaction; and that this is a fact there is no doubt. The only difficulty hitherto appears to have been to obtain nitric acid of a suitable strength. This has scarcely been accomplished, as experiments have shown that the reaction proceeds with less rapidity as the acid gains density. But where lime-water is used this objection is removed, inasmuch as no free acid can exist in the liquid to retard the reaction: each atom of this acid being removed or combined at the moment of its formation, or immediately afterwards. There is no doubt that the presence of an alkali not only obviates this retardation, but actually induces, by its presence, the combination of the lower oxides of nitrogen with oxygen, thus, in fact, acting in a doubly advantageous manner.

The solution of nitrate of lime, formed in the column, is run into a proper cistern placed for its reception and conservation prior to its being converted into a dry or crystalline salt, which the inventor proposes to employ instead of nitrate of soda, as a constituent of the artificial manures now so much in request.

Perhaps the process would have been more perfect had it been more self-containing, and not dependent on outer circumstances for its perfect well-doing; that is, if the vitriol manufacturer, instead of having to depend on the purchase of this nitrate by other parties, could have used it himself. Were it cheaply decomposable, that is to say, were it possible to eliminate the nitric acid cheaply, it would be better; but it can only be decomposed with ease by the addition of some stronger acid, and the only one reasonably available for this purpose is sulphuric acid. By substituting this nitrate of lime for the nitrate of soda or potassa, ordinarily employed, one would certainly most effectually get back the nitric acid; but, unfortunately, sulphate of lime, a body of no value, would be pro-

duced, instead of, as now, producing sulphate of soda or potassa, salts in great and constant demand.

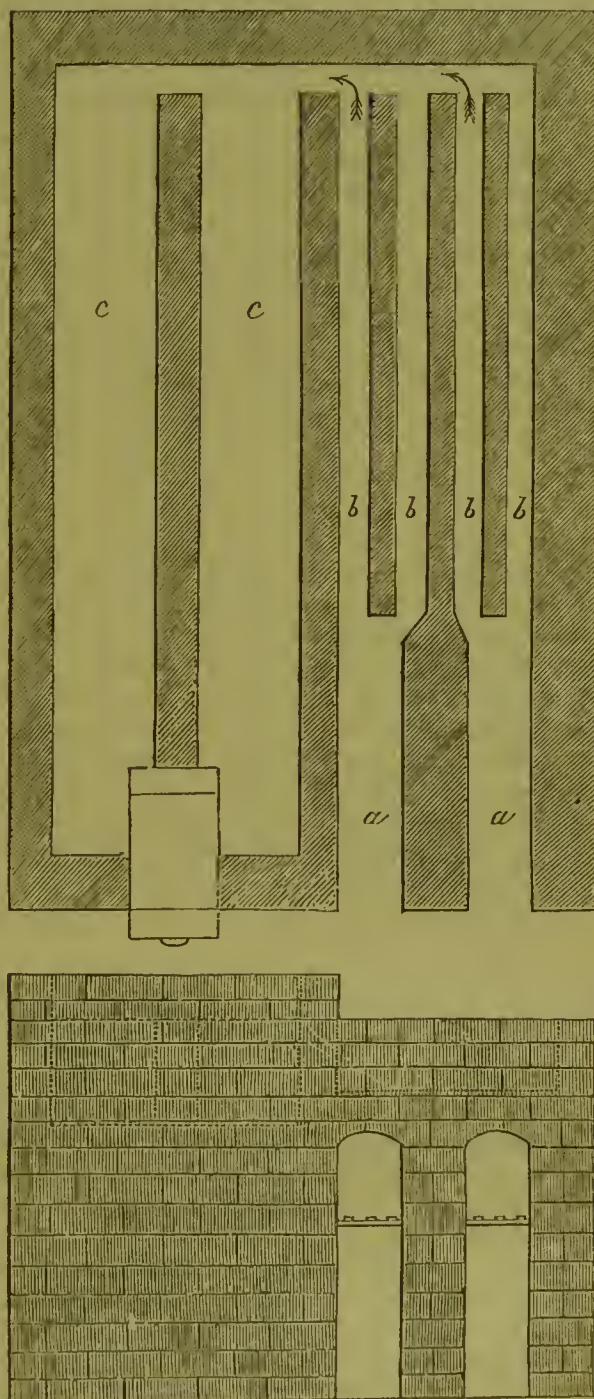
Of the value of processes for the recovery of the nitrous gas little need be said. The benefits they confer are apparent at once, recovering, as they do, the most expensive element in the manufacture, and not only being a saving of the money value of the nitre or its equivalent recovered, but further, when looked at in a politico-economical point of view, another phase presents itself: for were all sulphuric acid manufacturers able to work with half the nitrate they at present use, it would surely tend to reduce the price of this salt; and, if the maxim be correct, that price is regulated by supply and demand, then under the imaginary state of things just mentioned, one-half the quantity now used being thrown on the market, or what is the same thing, not used, must bring down the price of what could be sold, thus lowering a second time the cost of manufacturing sulphuric acid.

Concentration of Sulphuric Acid.—Sulphuric acid, as it exists in the chambers, though strong enough for many purposes, is not sufficiently so for sale, inasmuch as it is the object of the manufacturer to send it out as strong as conveniently may be, in order to avoid the necessity of conveying a quantity of useless water. It is concentrated up to a certain point in leaden pans; that is, until it has attained the density of 1.750; beyond this point it is not considered safe to push the concentration in lead. In order to bring it up to its maximum degree of concentration, or its conversion into what is termed rectified oil of vitriol, the extrication of the further remaining quantity of water must be performed in vessels of glass or platinum.

With respect to its concentration in lead a variety of plans are in use for this purpose. Much difference of opinion exists on this head amongst sulphuric acid manufacturers; their choice probably depending on convenience and situation. One manufacturer, for instance, prefers to concentrate his vitriol by passing the flame and products of combustion of a fire over the surface of his weak acid, the watery vapor being carried away with the smoke, *et cetera*. This plan appears to answer very well where no niceness with respect to the color and purity of the acid is demanded—as when the vitriol manufacturer is also a soda manufacturer, and uses up his own acid; but as the concentrated acid resulting from this mode of working is almost invariably very black and turbid in consequence of particles of coal-dust, *et cetera*, falling into the hot liquid, as well as from contact with the various carbonaceous bodies forming coal smoke, such acid would be scarcely saleable in the ordinary way to calico-printers, bleachers, and other such consumers. In order to avoid this, the manufacturer must employ an apparatus in which the liquid is kept clear from all or any such contaminations. For this purpose a pan in principle, though not in shape, resembling an ordinary pan or boiler, must be employed. This variety of concentrating boiler is in very general use, being, in fact, almost universal amongst those manufacturers who sell their acid; whilst the surface concentrator is as commonly employed amongst the soda manufacturers and others, who make the acid solely for their own use.

The following describes the plan of a manufacturer who makes for sale only. This plan is found to answer very well; it consists of two pans, placed side by side, one being placed higher than the other—so high that its contents can be emptied completely by means of a siphon into the lower pan. No joinings or solderings of any kind are admissible about these pans, the whole must be formed out of one solid sheet of lead,

Fig. 589.



the sides and ends being turned up simply: the lead is half an inch thick, the other dimensions of the sheet being thirty-three feet by seven feet six inches. To form such a pan, the sheet of lead is first spread out on the bed prepared to receive it; the plumber proceeds to mark off eighteen inches from each side of the sheet; this is to form the sides and ends of the pan. To faci-

litate the bending, a fire of shavings is made along the line of markings. When the lead has become sufficiently hot along these lines, he proceeds to bend up the sides, and to beat out any inequalities. The brickwork setting of the pans will be understood from the preceding figures, in which Fig. 589 represents the arrangement of the flues, previous to being covered in with the fire-tiles or iron plates on which the bottom of the pan is to be placed; the left hand portion represents the bed of the lower pan, while to the right we have that of the upper one. *a a* are the two fireplaces, the flame from which proceeds along the narrow flues or passages, *b b b b*; they turn off at the end in the direction of the arrows, and return beneath the upper pan, along the two wide flues, *c c*, and from thence pass into the wide flue leading to the chimney. Fig. 589 is a vertical section, lengthways, of the fireplace of the lower pan; *c* is the course of thick fire-tiles immediately over the fire, protecting the pan from the too great heat; a little beyond the fire thinner tiles are employed, which thin tiles are continued to the end. The two wide passages, *cc*—Fig. 589—beneath the upper pan are covered with iron plates, half an inch thick, on which the pan is placed. It will be understood from this description, that the tiles, or other supporting medium, diminishes in thickness, but increases in conducting power as the distance from the fire increases. This arrangement is necessary, for were iron plates used the whole distance, they would soon be burned through and destroyed in the immediate neighborhood of the fire; and, on the contrary, were thick tiles used for the whole distance, the latter portion of the arrangement near the end of the pan would offer too much resistance to the passage of the heat, and consequently a considerable portion would pass away without being absorbed.

Two such pans are capable of concentrating the acid produced from eight tons of sulphur per week of six days. There are pans at present in use capable of concentrating forty tons of vitriol weekly. Their mode of working is as follows:—The vitriol in the lower pan being of the proper strength, the workman proceeds to run it off into a vessel called a cooler, where it remains until cold. He runs it empty to within two or three inches; when this is accomplished, he proceeds to set a siphon into the upper pan, running the contents into the lower one, which lower one he fills within two or three inches of the top. When the upper pan is empty he refills it with the weak acid from the chamber; he then proceeds to fire the pan until next day, when he will repeat the operations just described.

The other description of pan, the one spoken of as a surface concentrator, is of the following description: Fig. 590 being a vertical section lengthways, the fireplace is at *a*, the flame, *et cetera*, proceeding in the direction of the arrows over the surface of the dilute acid at *b*, when it descends into the flue, carrying with it the evaporated water. It resembles—with the exception of some particular details, to suit the material to be evaporated—the furnace described under the head ALUM in this work, Fig. 89; but in the case of sulphuric acid, the furnace has to be lined, so to speak, with lead; and this lead being liable to fuse at a comparatively low temperature, much ingenuity is

displayed in the methods adopted to prevent, as far as possible such an occurrence. One mode of accomplishing this is shown in Fig. 590, where *d d* is a section of the leaden pan, inclosed in brickwork, to prevent

Fig. 590.



the action of the flame. The side of the pan is built up to the furnace dam, *e*; then within the pan a close row of firebricks, *b*, are placed on end, but not cemented in any way. Thus the sides of the pan are inclosed between brick walls, it only remains to cover up the space, and this is done by placing firebricks on the top, resting partly on the furnace dam, and partly on the row of bricks just mentioned; the flame is thus completely kept off the lead. This is repeated all round the pan's sides and ends being equally protected. Some manufacturers employ a slightly different arrangement, although on the same principle. A covering brick, expressly made for the purpose, is employed; these bricks are made of the proper size, with an indentation or channel formed in them; this channel being for the purpose of inclosing the upper edge of the pan, side or end. This arrangement is shown in Fig. 591, where *a* is the pan edge; *b*, the brick or tile, with its channel, *c*, inclosing the edge of the pan.

Fig. 591.



Though these precautions would appear to be sufficient, yet the manufacturer usually avails himself of another invention, which consists in running a stream of cold water round the pan's edge. This is effected by burning or fusing—by means of the hydrogen apparatus mentioned in another portion of this article—to the edge of the pan a leaden tube of a D shape, the flat side being next to the pan; a section of this pipe is shown in Figs. 590 and 591. This arrangement has a current of cold water constantly flowing through it.

These vitriol pans are often of immense thickness, in some cases the lead of which they are made is an inch thick; but as the heat does not, as in the previously described pans, penetrate through this, it is immaterial. They are worked rather differently to the other pans, inasmuch as it is necessary to cool them to a much lower temperature before running them off. Before this is done the fire must be slackened, or rather put out; for, were the pan to be emptied while the fire was burning with its usual vigor, the pan sides might get so hot as to become soft, and fall or bend down. The upper portion is an arch of firebrick, through which a hole is pierced over one corner of the pan;

through this hole the siphon is inserted for drawing off the finished vitriol; it is also refilled with dilute acid through this. The workman ascertains the progress of the concentration, or its completion, in all cases by taking out a portion from time to time, and placing the vessel containing this trial sample in water to cool. When cold enough, he ascertains the density by means of the hydrometer. When finished it must, as before stated, be of the density of 1.750, or of the strength of 150° on TWADDELL'S hydrometer—the instrument most used in this country—when at a temperature of 60°. When of this density, he draws out the fire and proceeds to run the vitriol into what are called coolers, which, as their name indicates, are for the purpose of holding the acid until sufficiently cool to run off into the glass bottles called earboys, for sale or transport to its destination.

These coolers, which are simply shallow lead vessels almost identical with the first-described pans, are, like the latter, formed out of an entire sheet of lead, sometimes half-inch, often of quarter-inch thick. This is, of course, an indifferent matter. The half-inch will last much longer, nevertheless it is not advisable to make them of less than quarter-inch. These coolers are set on iron plates in the manner described with reference to the upper pan; but the ends of the flues are open to the air, which, circulating through these passages, carries off the heat. The sides and ends are held up by brick walls or other convenient supports.

Very good and efficient coolers are constructed as follows:—The dimensions of an iron vessel, capable of holding the quantity of vitriol likely to be run off from the pan, are calculated—these parts are cast of about half-inch thick iron in such a manner that the whole can be securely bolted together. No care is requisite with respect to the accurate fitting of the various joints, as the whole must be lined with say quarter-inch lead. This lead must be turned over the upper edge and flattened down so as to prevent any infiltration of acid between the iron and the lead. If this is not attended to, the acid which finds its way down will act upon the iron, producing protosulphate of iron in masses. These will continue to grow in size, and in so doing will push the lead from the iron, producing misshapen prominences, which will finally destroy the cooler, or rather necessitate the removal of the lead lining, the cleaning the surface of the iron, and finally relining with lead. Two of these coolers, of six feet square and two feet deep, have been in use for some time; they cool the vitriol very rapidly. They are not set on the floor, but on two low walls of brick, so that almost the whole surface of the iron is exposed to the cooling influence of the atmosphere, and the heat is quickly carried off.

It is possible to construct coolers by simply lining a wooden cistern with lead: such are used for crystallizing various salts; but it is a question whether they can be recommended, inasmuch as the cooling must be very slow, on account of the bad conducting quality of the wood which forms the coating to the lead.

In most vitriol works two coolers are used in connection with the pan or pans. Suppose they are called No. 1 and No. 2, the mode of working resem-

bles that of the pans first described; that is, No. 1 is supposed to be cool enough to bear bottling. When this is done, the contents of the upper cooler, or No. 2, is now run into No. 1, while No. 2 is now ready to receive a fresh quantity from the lower concentrating pan. It will thus be seen that in working a set of concentrating pans and their accompaniments, four stages may be recognized. The upper pan partially concentrates the acid ready for the lower pan, which then completes the concentration. From this lower pan it is run into the upper cooler, where it loses the greater portion of its heat, and finally it is run into the lower cooler, where it remains until quite cold or nearly so.

The system just described is in constant use in some works, but is not by any means universal, each manufacturer limiting the extent of his apparatus to his wants. The arrangement most usually seen, especially in small works, is a single boiling-down pan, as it is technically termed; the heat passing beneath it up one flue and returning to the same end down another, after which it passes to the chimney. This pan is accompanied by one cooler. The raw acid from the chamber is run into this single pan, where it is concentrated up to the proper point, after which it is run into the cooler, where it stays until cold; and if the pan is ready to run off again before the vitriol in the cooler is cold enough, there is no help for it, but drawing the fires and letting it stay in the pan until it can be accommodated.

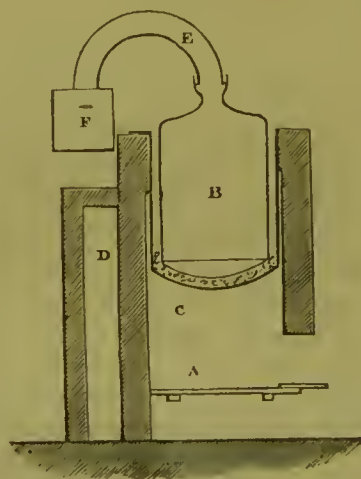
There is no objection to this system except, perhaps, that it is not calculated to do much work; still it answers sufficiently well for small manufacturers.

The manufacture of sulphuric acid has now been traced to the completion of a commercial product, which, in the language of the trade, is called brown oil of vitriol, in order to distinguish it from a product of still higher concentration, to be immediately described. This brown oil of vitriol is used to a large extent by bleachers, calico-printers, dyers, and others; its brown color, from which it derives its name, is due to a certain amount of organic matter which finds its way into it, and which, subjected to the joint action of the acid and heat, becomes carbonized, and colors the whole of a dingy-brown hue. This tint is often augmented from accidental circumstances. Sometimes the workman lets the rag or paper protector, with which he covers his hand while setting the siphon, drop into the pan, at other times fragments of wood-shavings or sawdust find their way into it; when this is the case the vitriol well deserves its name of brown; perhaps, under these circumstances, black would more nearly designate its color. When such an accident occurs, it is usual to destroy this black or brown color by sprinkling a small quantity of some highly oxidizing body into the vitriol while hot in the pan; either nitrate of potassa or soda answers well for this purpose. Finely powdered black oxide of manganese may be used. These bodies yield up sufficient oxygen to the black matter to destroy it, or convert it into some colorless body which does not offend the eye.

Monohydrated Sulphuric Acid—Rectified Oil of Vitriol—English Oil of Vitriol.—Brown oil of vitriol is not sufficiently strong for several purposes; amongst others may be enumerated the manufacture of the dyeing

compound known in commerce as extract of indigo, sometimes called sulphate of indigo. Fuming Nordhansen acid is often directed to be employed in the formation of this body, but in this country it is usual to employ the strongest English sulphuric acid. In order to procure this acid the following methods are adopted:—It has been stated previously that the concentration cannot be safely conducted in lead beyond the density of 1.750, for if driven further, not only would the metal be rather strongly acted upon, but there would be considerable risk of the pan-sides falling in, in consequence of the softening of the lead; so high would the degree of heat become before the last portion of water could be driven off. The further concentration, then, must be performed in vessels made of a material which will withstand the corrosive action of the boiling acid, and which is comparatively infusible. Glass at once suggests itself or some variety of earthenware, such as porecelain, or, amongst the metals, platinum or gold. Of the former two glass offers most advantages, and of the two latter materials platinum is preferable, inasmuch as it resists acids quite as well, and is much cheaper than gold. Glass has been employed in the concentration of vitriol from very early times, perhaps from the period when sulphuric acid began to be understood, and its manufacture attempted on a very small scale, doubtless before the introduction of leaden pans. Platinum, on the other hand, is a comparatively late introduction. The glass vessels employed in the last concentration of sulphuric acid, or, as they are technically known, retorts, resemble very much the bottles or carboys used to transport vitriol from place to place. Their figure is shown in section in Fig. 592, which represents the whole arrangement when at work.

Fig. 592.



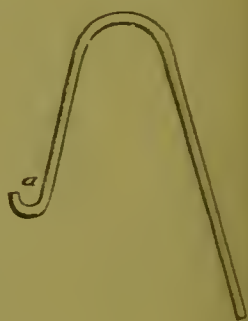
These retorts vary some little in size, manufacturers having lately begun to use much larger ones than were formerly employed. Those in use at the present day are capable of holding more than twenty gallons of liquid, inasmuch as after the rectification or concentration there remains in the retort sufficient vitriol to fill two carboys. This is equal to twenty gallons.

The mode of working can be gathered from the drawing, where A represents the fireplace; the flame, *et cetera*, from the fire plays round the cast-iron pot, C, finally making its exit into the flue, D. On the bottom of the

iron pot just mentioned a quantity of dry sand is laid; and on this the retort, B, is placed, the sand serving as a steady support for it. The retort is not, as is sometimes supposed, surrounded with sand; for, if this were done, it would run some risk of being broken, by the material retarding the cooling when the rectification was over.

The retort being placed, as in the drawing, it is filled with cold brown vitriol; and when this is done the fire is lighted; the arm, E, is put into its place; the apparatus gradually warms up, and eventually the acid boils; water, with a little sulphuric acid, distils off. This vapor passes off by the stoneware arm, E, into the leaden draught-pipe, F, where a quantity of it condenses; but the greater portion finds its way from thence into the chimney. The contents of the retort are kept boiling for some hours, or until the brown color entirely disappears; for this appears to be the only reaction by which to determine the conclusion of the rectification. It would appear that the organic matter resists the destroying or oxidizing action of the acid, until it has reached its highest point of concentration and temperature. When the clearing has taken place, the fire is withdrawn from beneath the pot; and the whole arrangement is

Fig. 593.



allowed to cool down to a safe temperature, when it is drawn off into carboys. This drawing off is effected by a peculiar siphon, being in fact what is known as MITSCHERLICH'S siphon; but in this case, on a rather large scale, as shown in Fig. 593, it consists of a siphon, with the shorter of its two legs turned back upon itself, as shown at a. This turned-up portion should be as short and as close to the siphon leg as possible, in order to be the more easily inserted into the neck of the retort; it is rather exaggerated in the drawing. In order to withdraw the concentrated acid from the retort, the workman first removes the earthenware arm; the siphon is filled with water, the man keeping his thumb firmly closed over the orifice of the longer leg. The shorter leg is inserted into the retort, and gently placed on the bottom; the workman then removes his thumb for a few seconds, until the acid has driven before it the water with which the siphon was charged; when this is done, the end is directed into a carboy which has been placed in readiness by an assistant. When the carboy is full the orifice is again closed by the thumb, while the full carboy is removed and replaced by another empty one. The whole range of retorts are emptied in this manner.

This product is the strongest English sulphuric acid: it is colorless or nearly so, and is of the density 1.850, or 170° on TWADDELL'S hydrometer.

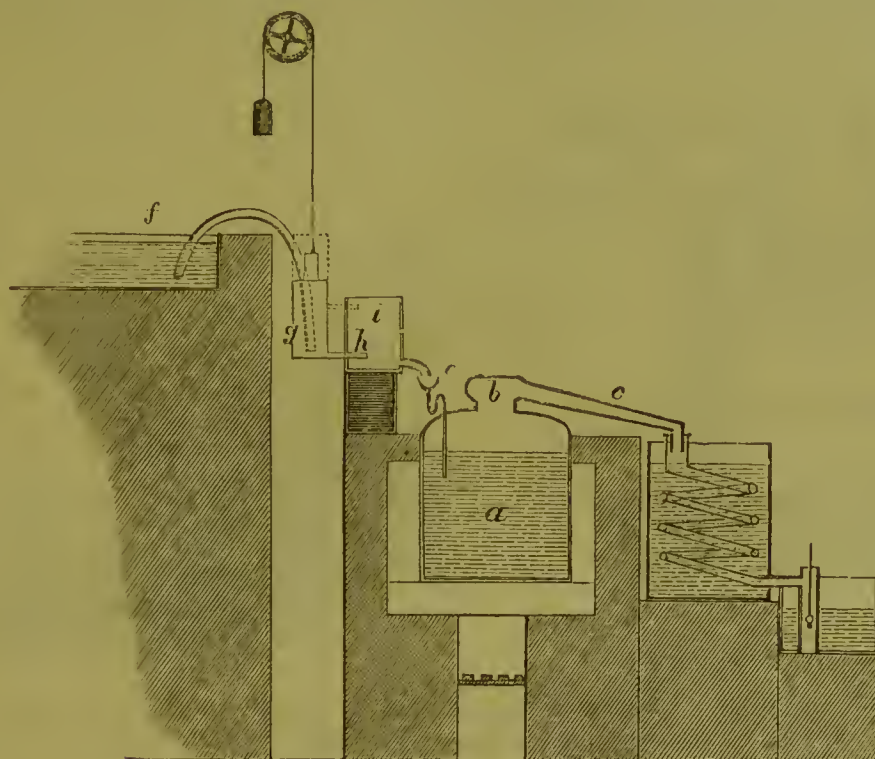
When treating of the commencement of this process, the retort was directed to be filled with cold brown oil of vitriol; it was supposed in this case that the retort was newly starting; but as one charge is now supposed to have been worked off, it will be more or less warm, and the introduction of cold vitriol at this junct-

ture might possibly fracture it. Therefore, it will be necessary to recharge it with warm vitriol, or with vitriol as nearly the same temperature as the retort as possible; and this must be made a rule, if annoyance would be avoided.

It is usual to find in books treating of this matter, the apparatus for rectifying in glass described as con-

sisting of a great number of the retorts, with their accompanying sandpots, *et cetera*, set in a battery, that is, a number of them heated by one fire. Though this may have been the case at one time, it is not the practice or custom to operate in this manner at the present day. Such an arrangement could not have worked as well as the present one, the probabilities being that the

Fig. 594.



retorts which were placed nearest the source of heat, would arrive at their maximum point of concentration some time before those at the end of the arrangement furthest from the fire were finished; in such a case it would have been necessary to have kept on firing until the whole set were done. The result would be that a considerable quantity of sulphuric acid would have distilled off the finished retorts, while those in the rear were being finished. In the present arrangement each retort is by itself, has its own fire, and consequently works totally independent of its neighbors.

The defect of this system of operating is the great fragility of the operating vessel, and the consequent liability to fracture either from a blow or other accident of the kind, or from change of temperature. The room or shed in which a concentrating plant of this description is working, should be closed, and every precaution taken to prevent the access of draughts of cold air or other cooling influence. It is no uncommon occurrence for two or three retorts to be cracked round the top, from the sudden rush of cold wind through an opened door, in such a manner that the whole upper part of the retort could be lifted off; the crack having gone completely round it, and severed the upper portion as completely and as straight along the protecting edge of the sandpot, as though it had been done with a diamond. Mr. JONES of Bristol took out a patent in the year 1845, for a protector to obviate this

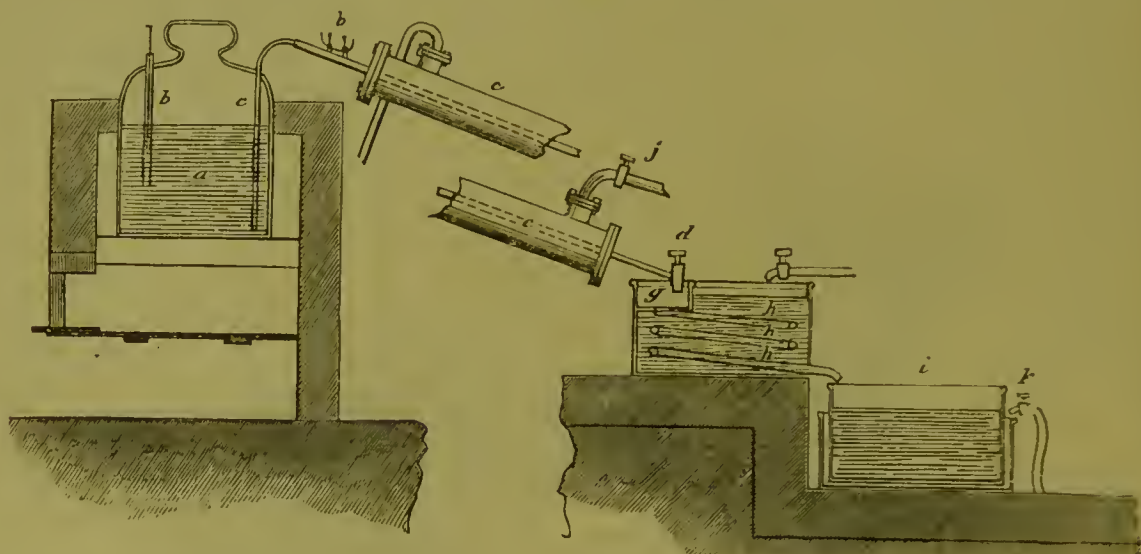
accident. The protector consisted of a sort of sheet-iron bell-jar, if such a term may be used; this bell-jar has a hole cut in the upper portion, so that the whole may be placed over a retort when in work, the neck of the retort protruding through this orifice, while the lower edge of this cover rested on the upper edge of the sand-pot. Such an arrangement effectually protects this part of the retorts from cold draughts, or drops of cold liquid, which, as may be easily imagined, are equally destructive. In fact, any cool or cold body coming in contact with the heated glass is fatal to it, causing much inconvenience; for not only is the retort itself destroyed, but the contents are lost, also creating the greatest annoyance and discomfort, for the vitriol trickles or runs out, and, coming in contact with the red-hot pot, is converted into vapor of a most suffocating kind, filling the whole place. This calamity is without remedy; and even though a remedy were to present itself, it would be impossible to enter the place, and apply it, without running considerable risk of suffocation.

These risks and drawbacks were doubtless the stimulants which brought out the platinum retort, this costly, but efficient substitute being safe from the casualties just described. This retort, with its appendages, is shown in Figs. 594 and 595. The former is a vertical section in front; *a*, is the body of the retort; *b*, the head; *c*, a platinum tube leading from the head to a

leadern worm, which worm is kept immersed in water; *e* is a platinum funnel, the tube of which is S-shaped, to prevent the return of any vapor. The brown acid which is kept in the cistern, *f*, under which the waste heat passes, is run into the body of the retort without the aid of any tap or valve by means of the at-first sight rather complicated, but really simple apparatus shown in the figure, where *g* represents a round vessel in which a tube, *h*, is inserted very near to the bottom; *i* is another leaden vessel, which has a slit in the side

from the top nearly to the bottom, along which slit the tube, *h*, slides, when the vessel, *g*, is moved up or down by means of the chain and pulley. A siphon, which is kept constantly set, connects the stock cistern, *f*, with the vessel, *g*. The apparatus, when in the inactive state, as represented by the dotted lines, is as follows:—The siphon is full of vitriol, but the surface of the acid in the cistern being on a level with that in vessel *g*, no flow can take place; when the vessel, *g*, is lowered, the levels become altered; and as the leg

Fig. 595.



the siphon, which is in vessel *g*, becomes the longer, the acid begins to run into this vessel, and from this into vessel *i*, and thence into the funnel.

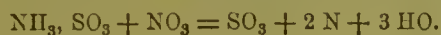
The other portions of the apparatus being at the back, are shown in Fig. 594, which is a side view; *a*, as before, is the body of the retort; *b*, is a platinum tube about three-fourths of an inch in diameter, in which a glass float is placed to indicate the depth of liquid in the still; *c*, is a siphon, also of platinum, of the same diameter as the tube just mentioned. This siphon is inclosed in an iron tube, *d*; between these two tubes a current of water can be passed. The siphon terminates in a platinum tap at *e*. The body of the still rests on a circular tile of refractory clay; the fire being below this tile, the flame rises at the back of the still, circulates round the sides, and finally passes from thence under the stock-pan. The course is shown in Fig. 595.

The mode of working this still is as follows:—The workman fills up his still a few inches above the highest point the flame is likely to reach; the fire is lighted and kept on until the contents are brought to boiling. The concentration then commences; vapor passes off through the head and conducting tube into the worm, where it again resumes the liquid form, running out into a vessel placed to receive it. This liquid is always acid, but at first it is very weak; it eventually reaches a density of 1.2400. When this strength is attained, the workman knows that the highest degree of concentration is arrived at. If the running-off siphon, *c*, is not set, he proceeds to do this by closing the tap, *e*. The two plugs are removed in the funnel, *f*, and the siphon is filled with vitriol; the plugs are replaced. It

now only remains to open the tap, when the contents of the still begins to run off. The tap is allowed to remain open, until from three to four inches of the still contents are drawn. The workman is guided in this by the indications of the glass float before spoken of, which serves as a gauge. The acid falls into the eup, *g*, thence it flows through the serpentine coil of pipe, *h, h, h*, which is immersed in water; and finally it emerges still slightly warm at the end of the coil, and runs into the receiving vessel, *i*, which vessel stands within another one, a stream of cold water from the tap, *k*, circulating between the two. The water tap, *j*, is also turned, when running off, so that a stream of cold water cools the siphon itself. When the operation is over, the workman proceeds to repeat the course of operations just described; he fills up his still to its former level, attends to his fire, heats it up to the proper point, and again allows the acid to run off.

Such an apparatus, the still itself having a capacity of from seventy to eighty gallons, is capable of producing thirty carboys of rectified oil of vitriol in twelve hours, two carboys being all that a glass retort could produce in twenty hours; but this of course is owing to the latter requiring such a length of time to elapse before its contents can be safely drawn off. A retort of the above dimensions, with the siphon and float case, costs about fifteen hundred pounds, the price varying according to the thickness of metal, and consequently weight of platinum, yet it is generally admitted to be a more economical plan of operating than the glass retort system. But it is not free from disadvantages; it is necessary to be careful that the vitriol contains no nitrous

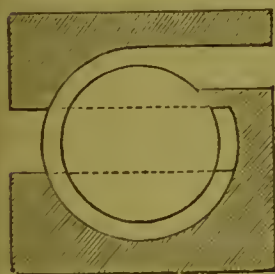
compound, for if this be the case, the platinum is rapidly attacked. To obviate this, it is usual to add a quantity of sulphate of ammonia to the acid, while in the leaden concentrating pan, before it enters the still; the action of this salt is to decompose the nitrous body usually existing in vitriol. It is supposed that the following is the decomposition which takes place, assuming nitrous acid to be the body present:—



This may occur in some cases, but it is not the invariable result. If a *little* sulphate of ammonia be dissolved in a small quantity of the nitrous vitriol of GAY-LUSSAC'S column, and the whole heated in a test tube, either NO_2 or NO_3 is evolved; nitrogen very probably is given off at the same time, but it is not the only body eliminated. When a rather large excess of sulphate of ammonia is employed, sulphide of hydrogen is formed in the still, and can be detected by the smell at the end of the condensing worm; undoubted evidence of its presence has been detected by means of lead paper. The only rule that can be laid down for guidance as to the quantity to be used, is the addition of an increased quantity of the salt each day until nitrous bodies cannot be detected in the finished vitriol; the workman at last obtains a good idea of the quantity to be added.

Sulphuric acid is brought to a saleable condition by the employment of one or other of the methods just described; but although these methods are universally employed, others have been proposed. The patentee who proposed to generate the steam necessary for the chamber by the combustion of the sulphur, also proposed to concentrate vitriol

Fig. 596.



or any other liquid by means of the heat from this source, hitherto, in the inventor's opinion, wasted. The idea is very ingenious, perhaps more so than practical; but it would appear to be doubtful whether it is possible to concentrate vitriol at all by this process. The probability is that the sulphur

would begin to sublime before the vitriol could be brought to the proper strength. The process is not in use in any part of the country, so that one may naturally infer that it is without practical value.

Perhaps the most ingenious proposal for the concentration of vitriol is the one about to be described, the prevailing principle of which is that of carrying over its surface streams of hot air, which, liberating and combining with the water, carries it off. The apparatus consists of two distinct portions, the one devoted to the production of highly heated air, and the other to the concentration. The former portion of the apparatus consists of a series of iron pipes, *a*—Fig. 597—set in brickwork; these tubes are heated externally by the flame of the furnace, *b*, the products of combustion from which pass up the space, *c*; they then descend and circulate round the tubes, finally making their exit into the main flue by means of the openings, *d*. The cold air

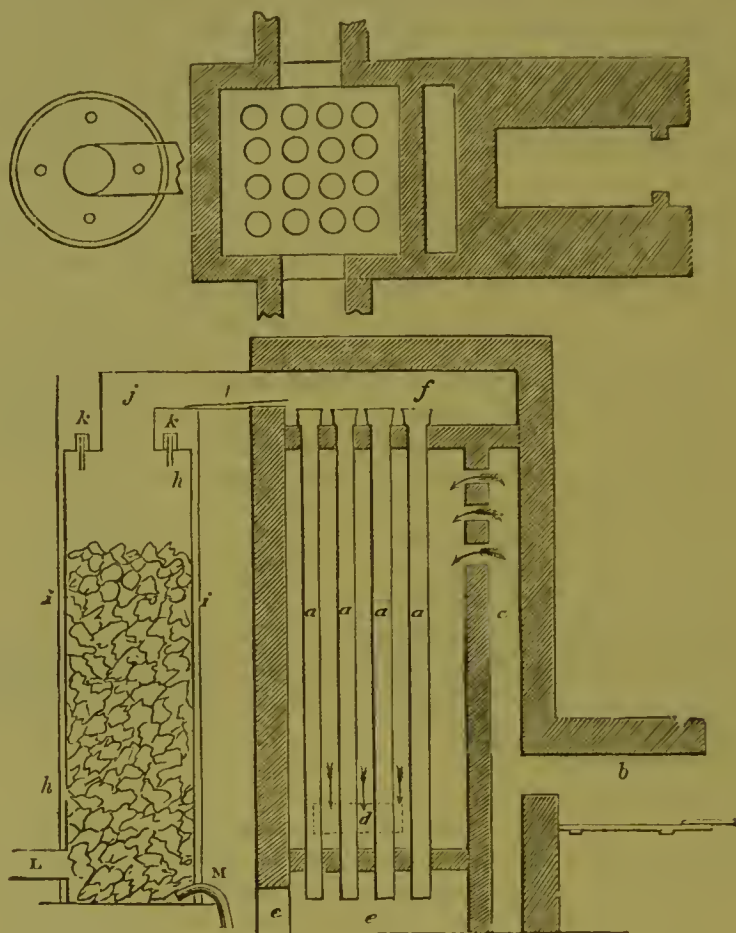
from without enters the lower ends of the tubes which project into the arched recess, *e*, passes up them, and, becoming highly heated during its progress, enters the space, *f*, and passes along the wide iron tube, *g*, and thence into the concentrator. The portion of the apparatus devoted to the concentration is constructed entirely of lead; it consists of two concentric cylinders, *h, h*, made of half-inch lead; *i i* is a small space, the use of which will be explained hereafter, which exists between them; both cylinders are closed at the bottom by being fused on to one sheet of lead; the inner cylinder is partially closed at the top, space only being left for joining on the leaden tube, *j*, which is a continuation of the iron tube, *g*, spoken of before, and is for the conveyance of the heated air. The inner column or cylinder is filled with coke, or other suitable material, which offers a large surface for the acid to spread itself over, at the same time being unattacked by it. The following is the method of working this apparatus:—The opening into the arched recess from which the cold air is drawn must be closed, or if there be a damper or register beyond the concentrator between it and the chimney, this must be pushed in. The furnace must be heated up until the pipes and the chamber containing them are of a good red heat. This state of preparation having been arrived at, the vitriol to be concentrated must be run on to the top of the inner cylinder; it runs down and fills up the space existing between the two cylinders, rising up to the mouths of and running down the tubes, *k, k*; these tubes are covered with lead caps, the bottom edge of these being immersed in the vitriol from an air-tight joint, which prevents any cold air being drawn in. The vitriol on flowing through these tubes spreads itself over the whole surface of the coke, wetting it thoroughly. When sufficient vitriol has been run in to saturate the whole of the coke, the hot-air current is allowed to enter it, penetrates every space and crevice in the mass, and heating the vitriol up to a high point, carries off its water finally when saturated, making its exit into the chimney by means of the wide tube or pipe, *l*. The vitriol becomes more and more concentrated, the nearer it approaches the lower part of the cylinder. When it has arrived at this point, if the amount of acid and hot air have been proportioned to each other, it will be found to be fully concentrated. It collects in a stratum at the bottom, until the surface rises sufficiently high to flow off into a proper reservoir or cistern through a bent tube, *m*. The use of the double cylinder has two advantages—it heats the sulphuric acid somewhat, previous to its admission into what may be called the concentrator proper; and also keeps the latter cool, or rather lessens the risk of its fusing if too great a heat should be employed.

The apparatus in the form just described, though capable of concentrating vitriol, cannot be said to be a success. The fusion of the lead in the upper portion was the weak point in this invention; in order to work the apparatus with practical efficiency, it was necessary to have the air highly heated, in fact the current of air may be said to have been red hot. Under these circumstances it was almost impossible to avoid the fusion of the lead tube which conveyed the hot air from

the heater. This great difficulty, combined with some minor ones which, however, might be obviated, caused the inventor to relinquish the idea. Although not an

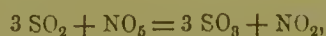
invention or process capable of being carried on in its present shape, yet, in the hands of a patient operator, it might be made to yield better results. It would

Fig. 537.



probably be a work of no little trouble and expense, yet if the anticipated result could be obtained, it would amply repay any trouble or expense that might be expended upon it.

Proposed Improvements in Manufacturing Sulphuric Acid.—The efforts of inventors in connection with sulphuric acid, would appear to have been directed to the substitution of some apparatus of smaller bulk, and less costly in construction, than the leaden chambers ordinarily employed. Perhaps the simplest process embodying the above idea is that of Messrs. M'DOUGALL and RAWSON, who included it in a patent obtained by them in 1848. It consists essentially in passing a stream of sulphurous acid gas through nitric acid by which sulphuric acid and binoxide of nitrogen— NO_2 —are obtained as follows:—



but the great point of the process is the continual conversion and reconversion of this NO_2 into nitric acid, to be again used as before. The inventors say, that the reaction which ensues may be best described by symbols. Thus when 3NO_4 —the NO_2 evolved in the first reaction becoming NO_4 by combining with the excess of oxygen, which as atmospheric air accompanies the sulphurous acid—is passed into water at a temperature of 100° , or upwards, $2 \text{NO}_5 + \text{NO}_2$ results. This NO_5 —or, two atoms of nitric acid—remains in solu-

tion, while the NO_2 , which is an incondensable gas, bubbles through the liquid, and, mixing with the air which is above the liquid, instantly takes two atoms of oxygen from it, and becomes NO_4 ; which, passing again through the liquid, becomes nitric acid and nitrous gas as before: and thus nearly the whole of the nitrous fumes or gas is reconverted into nitric acid. It should be observed that the use of this reaction is claimed in connection with several processes, such as the manufacture of oxalic acid, *et cetera*; but with regard to sulphuric acid, they further say—In our improved method of manufacturing sulphuric acid, we use a series of vessels, similar to that described in the first part of our invention—a modification of Woulfe's bottles, in fact—only that the first vessel of the series is connected with a sulphur burner. The mode of working is to fill the first vessel two-thirds full of nitric acid, and all the others one-third full of water, to charge the burner with sulphur, and then to put in motion the pneumatic apparatus connected with the last vessel of the series. Air is thus drawn over the ignited sulphur, so that sulphurous acid and air pass into a solution of nitric acid in the first vessel, when a portion of the sulphurous acid is converted with sulphuric acid, at the expense of the nitric acid; while the uncondensed sulphurous acid passes into the air, and nitrous gas into the next vessel; and so, as in the first part of the invention, we pass it alternately into water and air, till

the processes of oxidation and condensation are complete. When the working has been continued for some time, we find that the nitric acid has entirely passed from the first vessel, and we have in its place sulphuric acid nearly pure. The same would take place with each of the other vessels of the series, if the nitric acid which has been condensed in the vessels lower in the series, was not again returned to the higher ones, so that when we find the first vessel exhausted of its nitric acid, we remove the sulphuric acid which it contains, and supply it again with nitric acid, obtained from vessels lower in the series. We thus produce sulphuric acid without the loss of nitric acid; as the lower oxides of nitrogen, given off in the oxidation of sulphuric acid, are again converted into the higher oxides, and again used for the conversion of sulphurous acid into sulphuric.

The principle embodied in this process, namely, the perfect recovery of the nitric acid, has been the prevailing idea of many inventors. Some of the other processes to be described are based on the same reaction. About the same time as the date of the above patent, an ingenious modification of their process was being experimented on, of which the following description is an outline:—The apparatus consisted of a burner for the production of sulphurous acid, and an ingenious substitute for the WOLFE's bottles of the last-described process. The burner, *a*—Fig. 598—consisted of an iron chamber, closed up tight, with the exception of an inlet pipe for the admission of air for combustion, and an exit pipe for the sulphurous acid, proper means being allowed for the introduction of the sulphur. The condensing or the conversion part of the apparatus consisted of two leaden troughs or cisterns; but, as they were exact counterparts of each other, a description of one will suffice. This trough, shown in section in the figure, has, what may not be inappropriately called a false top, *b*, a few inches below the real top, *c*. This false top, which was to all intents a sort of shelf, had borders or edges soldered on to it in such a manner that had it been taken out and laid down with its under side upwards, it would have resembled a large, shallow, square dish. This shelf, as just stated, was fastened inside the cistern, within a few inches of the top, and in an inclined

To work this apparatus the two cisterns were first filled with water or weak vitriol, and the vessel, *d*, was filled with nitric acid; a quantity of sulphur was introduced into the burner, and a coal fire ignited beneath it; a stream of air was then turned on through the tube shown in front of the burner, this stream of air being supplied by a pair of bellows, or other suitable apparatus; when the burner attained a sufficiently high temperature, the sulphur ignited; sulphurous acid became generated; this proceeded along the pipe, *e*, and was discharged beneath the shelf, *b*. At this point it was met by a small stream of nitric acid, which trickled from the vessel, the gases rolled beneath the shelf, and from thence beneath the shelf of the second vessel. The reactions, it is scarcely necessary to observe, must have been precisely the same as those in the last-described process; the gases in this case being kept continually in contact with both air and water, and not alternately, as in the former case.

If, in the instances last given, the recovery and *ad infinitum* use of the nitrous gas has been the object, other methods have been invented or discovered by which the use of this body is proposed to be dispensed with altogether. In this latter class of projects, the oxidation of the sulphurous acid has been sought to be effected by the use of some catalytic agent, no cheap chemical body of an oxidizing character having presented itself capable of successfully rivalling the nitrates. The use of spongy platinum, in consequence of its possessing the requisite property in a high degree, naturally was the first suggestion. PARNELL says this was attempted by Mr. PEREGRINE PHILLIPS. His process consisted in simply mixing the sulphurous acid with excess of oxygen in the shape of atmospheric air, and passing this mixture over balls of spongy platinum at a red heat. The combination took place, and the vapor was received and brought to a liquid state by means of a condenser, like those already described, consisting of a column filled with pebbles, kept constantly wet by a stream of water.

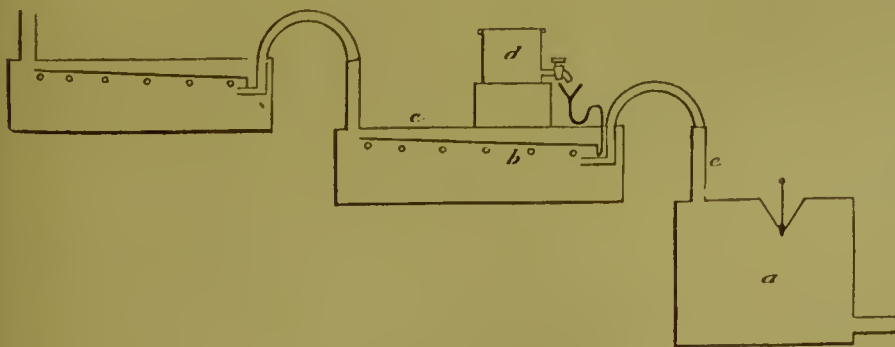
Eventually it was discovered that platinum was not the only body adapted to the purpose; other porous materials, it was found, were capable of effecting the desired union of oxygen and sulphurous acid; for SCHNEIDER states that he has succeeded in converting sulphurous acid directly into sulphuric acid by means of a porous body, for instance, pumicestone, and that this process may be employed for manufacturing sulphuric acid of 170° Twaddell, without the necessity of leaden chambers or of platinum retorts. This has the advantage of being an immeasurably cheaper material although it can scarcely be so active.

M. BLONDEAU describes another process of the same

position, so that one end was rather higher than the other by about two inches, thus giving it a gentle slope—the use of this will be seen when describing its action.

nature as the last. The author has studied the production of sulphuric acid in certain natural conditions. He instances the Rio Vinagre Pasiambo in

Fig. 598.



South America, the water of which, he says, according to an estimate of BOUSSINGAULT, supplies something like thirty-four tons of sulphuric acid in twenty-four hours; and also another instance in which three times this quantity was produced. M. BLONDEAU also examined the production of certain natural sulphates, such as those of potassa, soda, alumina, *et cetera*, and the conditions under which they are produced. Reasoning from his observations, he was induced to try whether certain natural conditions, under which sulphuric acid was produced, could not be imitated in the laboratory; he succeeded in the following manner:—A quantity of argillaceous sand was placed in a porcelain tube laid across a furnace, an apparatus for generating sulphurous acid was attached to one end, together with a tube from a gasometer containing air, and a retort for generating steam. A tube was attached to the other end of the retort, which led into a small vessel containing water, for the purpose of condensing any sulphuric acid which might be formed. The tube was heated red hot, and a slow stream of mixed air, steam, and sulphurous acid was passed through it. At the end of the experiment a quantity of sulphuric acid was found in the condensing flask. M. BLONDEAU suggests this as a mode of making sulphuric acid on the large scale.

WÖHLER has given us the results of some interesting experiments on the production of sulphuric acid by the instrumentality of certain metallic oxides, some acting catalytically, others as simple oxides, yielding up a portion of their oxygen, themselves being converted into lower oxides. He passed a mixture of sulphurous acid and oxygen over several metallic oxides placed in a porcelain tube, and kept at a red heat; but he does not say whether he passed water vapor simultaneously with them. He says that oxide of copper, sesquioxide of iron, and oxide of chromium, each separately employed, instantly caused the production of dense white fumes of sulphuric acid. A mixture of oxide of copper and oxide of chromium, prepared by precipitation, had in particular a very energetic action. The same amount of oxide appeared capable of converting an indefinite quantity of the gases into sulphuric acid. He goes on to say that the production of sulphuric acid proceeds so readily that the process will undoubtedly become practically employed. When sulphurous acid alone is passed over oxide of copper or iron, the first is reduced to red oxide— Cu_2O ,—and the latter to black oxide— Fe_3O_4 ,—with production of sulphuric acid vapors; but which, however, cease to appear as soon as the reduction is complete. WÖHLER gives the reaction of several other bodies; he also states that sulphurous acid, oxygen, and water vapor, passed through a tube alone, do not give rise to any sulphuric acid.

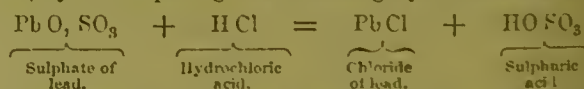
These ideas of WÖHLER appear not to have passed without notice, but on the contrary have been most unceremoniously claimed and patented.

Mr. G. ROBB, in a patent which he obtained, March 26th, 1853, proposes passing sulphurous acid and heated air over the surface of heated sesquioxide of iron—sulphuric acid is the product. He proposes also to take up the sulphuric acid as formed, by passing sulphurous acid mixed with air over a mixture of sesquioxide of iron and common salt—sulphate of soda is formed.

ALFRED TRULMAN obtained a patent for improvements in the manufacture of sulphuric acid when roasting copper ores, *et cetera*. This invention consists in passing the sulphurous acid resulting from the roasting copper ores, mixed with oxygen, atmospheric air, or other suitable material containing oxygen, in contact with heated platinum, oxide of iron, or other substance, having in a heated state the property of causing the combination of sulphurous acid and oxygen. The inventor also claims these bodies when diffused in burnt clay, pumicestone, or other suitable body.

Another process proposed for the manufacture of sulphuric acid is that of M. MARGUERITTE. It is entirely different from any yet described; it consists essentially in the separation of the already formed sulphuric acid from sulphate of lime. It is as follows:—Phosphate of lead is decomposed by hydrochloric acid; the phosphoric acid thus obtained is mixed with sulphate of lime, and the mass is calcined, when phosphate of lime remains and sulphuric acid is expelled. The phosphate of lime is decomposed by boiling with the chloride of lead already obtained, when phosphate of lead is again produced; this is again decomposed by hydrochloric acid, and the phosphoric acid set free again employed in the decomposition of a fresh portion of sulphate of lime. In this process the hydrochloric acid is lost in the form of chloride of calcium. It must consequently always be replaced, but when the sulphuric acid produced is employed in the decomposition of common salt for the production of sulphate of soda, the necessary quantity of hydrochloric acid is always reproduced, with the exception of unavoidable losses. By this process sulphuric acid may be separated from sulphate of baryta and other sulphates. He then proceeds to state that, if necessary, quantities of hydrochloric acid may be obtained from chloride of magnesium by heating it to redness when it is decomposed, especially when mixed with clay. This process is, however, not very likely to come into operation; it would require more hydrochloric acid than the author appears to calculate upon. If the composition of bone earth were CaO PO_3 , there would be a possibility of making vitriol by the reproduced hydrochloric acid.

Sulphate of lead has been patented for the same purpose, by decomposing it with strong hydrochloric acid—

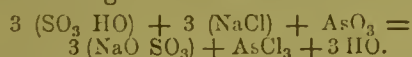


Impurities in Sulphuric Acid.—Sulphuric acid of commerce invariably contains lead. It is not difficult to account for the presence of this body when one reflects how much the acid is in contact with this metal in the chambers, concentrating pans, *et cetera*. Lead always makes its appearance as sulphate when strong acid is diluted with water, the concentrated liquid being able to dissolve a portion of this salt which, when diluted, it is not able to retain. Nitrous compounds are found also, together with traces of hydrochloric acid. Traces of selenium have also been detected. Arsenic is a common impurity, derived usually from the iron pyrites, from which much acid is made. Traces of arsenic have also been detected even in vitriol made from commercial sulphur. Sesquisulphate of iron has also

been found to be present. For the great majority of purposes these impurities are not found inconvenient in the arts; while, on the other hand, for some special uses, a process of purification must be had recourse to.

Purification.—When this is required for analytical or other purposes, distillation must be had recourse to. This, in the case of sulphuric acid, is a disagreeable process, not altogether free from danger, from the violent concussions occurring in the retort. It is usual to put a quantity of strips or fragments of platinum into the acid to obviate this bumping. A very simple condensing arrangement is necessary. The beak of the retort merely requires insertion rather loosely into the neck of a flask or wide tube.

For the purification of sulphuric acid from peroxide of nitrogen, nitric, or arsenious acids, Dr. J. Löwe recommends heating it, in the first place, with oxalic acid. This acid, heated with strong sulphuric acid, becomes first dehydrated, and then, as is well known, decomposes. Carbonic acid and carbonic oxide gases are given off. This carbonic oxide, being in the nascent state, has a strong tendency to deoxidize any highly oxidized body; therefore the peroxide of nitrogen and nitric acid give up a portion of their oxygen, becoming reduced to nitrogen, or nitrous oxide—NO—which bodies are not capable of being retained by the sulphuric acid, and therefore fly off. A temperature of 230° is requisite; at this heat the oxalic acid readily decomposes; it is added to the sulphuric acid, to be purified in small proportions in a dry state, as long as the sulphuric acid continues of a yellow tinge, and until a sample allowed to cool fails to show the presence of nitrous compounds, when heated with protosulphate of iron. The same author proposes eliminating the arsenic from sulphuric acid by converting it into chloride of arsenic, which is very volatile. The vitriol is heated in a flat dish, and small quantities of finely powdered chloride of sodium are added, stirring all the while with a glass rod. The arsenic passes off; the following being the reaction, the arsenic existing as arsenious acid:—



The operation must be conducted under a chimney, or other place where the arsenical fumes will be instantly carried off, so as not to injure the operator.

To avoid the troublesome and dangerous process of distillation, AUGUSTUS A. HAYES proposes to purify sulphuric acid in a very simple manner, namely, by crystallizing it. He first adds a small quantity of saltpetre to the acid while hot, in the leaden pan, and at a density if cold of 1.760. This destroys all organic matter, brownness disappears, and the acid becomes clear. A little sulphate of ammonia is now added, to destroy any excess of nitrate, as well as any nitrous compound already existing in it. The acid is now concentrated to a density of 1.780, and run off into deep vessels of lead, which are allowed to cool to a temperature of 32°; they stand so until clear; they are then run off into shallow lead vessels, so placed that they may become refrigerated to 0°. The acid, which has now nearly the composition $\text{SO}_3 \cdot 2 \text{HIO}$, would solidify if allowed to remain long enough; but the vessels must stand only until one half the bulk has

assumed the crystalline state; the mother liquid is then poured off. This mother liquid may be used for any ordinary purposes, such as the decomposition of nitrates, common salt, *et cetera*. The crystals are broken up after being washed with pure acid of a former operation, and are fused in a glass or porcelain vessel, when they form pure sulphuric acid.

Detection and Estimation of Sulphuric Acid.—Sulphuric acid is detected by means of a salt of baryta—this earth being capable of separating it from almost any combination, forming with it sulphate of baryta. In some cases, when testing for sulphuric acid, it is necessary to be very cautious; for instance, when endeavoring to ascertain its presence or otherwise in the nitric or hydrochloric acid of commerce, it is necessary to dilute these acids before adding a salt of baryta. If this is not done the nitrate of baryta, or chloride of barium, will itself be thrown down as a crystalline precipitate, liable to be mistaken for sulphate of baryta; but, if so, the addition of water to the precipitate will cause it to disappear, which will not be the case if the precipitate is sulphate of baryta. This latter salt, being very insoluble in water, furnishes us with a correct method of estimating sulphuric acid; for this purpose a weighed portion of the acid or any of its salts is placed in a beaker glass, and diluted with or dissolved in water. If it is a sulphate, the solution should be made *slightly acid* with nitric or hydrochloric acid, but if it is sulphuric acid alone that is being examined this addition is unnecessary; in either case the liquid is boiled, and, while boiling, a solution of chloride of barium or nitrate of baryta is poured in; the whole is allowed to boil a little longer, when it is removed to cool and settle. A little of the clear liquid above the precipitate is then tested, by the addition of a fresh portion of the baryta salt. If a precipitate is produced, it shows that all the sulphuric acid has not been thrown down, in which case it is necessary to add more of the barytic solution and boil again; if, after settling and further addition of baryta, no precipitate is produced, the whole must be thrown on to a filter, washed carefully with hot water, and dried. It is then ignited in a platinum or porcelain crucible and weighed; 116.6 parts, or one equivalent of sulphate of baryta, are equal to forty-nine parts, or one equivalent of monohydrated sulphuric acid, or forty parts of anhydrous acid. This method would be found too tedious to follow, except on special occasions; ordinarily the manufacturer relies on the indications of his hydrometer—that is, he takes the density for his guide. To enable us to arrive at the real value of the sulphuric acid from the density, several tables have been drawn up, of these. Dr. URE's is commonly used.

AMOUNT OF DRY ACID IN SULPHURIC ACID.

$\text{SO}_3 \text{ HIO}$.	Specific gravity.	SO_3 .
100	1.8485	81.54
99	1.8475	80.72
98	1.8460	79.90
97	1.8439	79.09
96	1.8410	78.28
95	1.8376	77.46
94	1.8336	76.65
93	1.8290	75.83
92	1.8233	75.02
91	1.8179	74.02
90	1.8115	73.39

AMOUNT OF DRY ACID IN SULPHURIC ACID—*Continued.*

SO ₃ HO	Specific gravity.	SO ₃
89	1.8043	72.57
88	1.7962	71.75
87	1.7870	70.94
86	1.7774	70.12
85	1.7673	69.31
84	1.7570	68.49
83	1.7465	67.68
82	1.7360	66.86
81	1.7245	66.05
80	1.7120	65.23
79	1.6993	64.42
78	1.6870	63.60
77	1.6750	62.78
76	1.6630	61.97
75	1.6520	61.15
74	1.6415	60.34
73	1.6321	59.52
72	1.6204	58.71
71	1.6090	57.89
70	1.5975	57.08
69	1.5868	56.26
68	1.5760	55.45
67	1.5648	54.63
66	1.5503	53.82
65	1.5390	53.00
64	1.5280	52.18
63	1.5170	51.37
62	1.5066	50.55
61	1.4960	49.74
60	1.4860	48.92
59	1.4760	48.11
58	1.4660	47.29
57	1.4560	46.48
56	1.4460	45.66
55	1.4360	44.85
54	1.4265	44.03
53	1.4170	43.22
52	1.4073	42.40
51	1.3977	41.58
50	1.3884	40.77
49	1.3788	39.95
48	1.3697	39.14
47	1.3612	38.32
46	1.3530	37.51
45	1.3440	36.69
44	1.3345	35.83
43	1.3255	35.06
42	1.3165	34.25
41	1.3080	33.43
40	1.2999	32.61
39	1.2913	31.80
38	1.2826	30.98
37	1.2740	30.17
36	1.2654	29.35
35	1.2572	28.54
34	1.2490	27.72
33	1.2409	26.91
32	1.2334	26.09
31	1.2260	25.28
30	1.2184	24.45
29	1.2108	23.65
28	1.2032	22.83
27	1.1956	22.01
26	1.1876	21.20
25	1.1792	20.38
24	1.1706	19.57
23	1.1626	18.75
22	1.1549	17.94
21	1.1480	17.12
20	1.1410	16.31
19	1.1330	15.49
18	1.1246	14.68
17	1.1165	13.86
16	1.1090	13.05
15	1.1019	12.23
14	1.0953	11.41
13	1.0887	10.60
12	1.0809	9.78
11	1.0743	8.97
10	1.0682	8.15
9	1.0614	7.34
8	1.0544	6.52
7	1.0477	5.71
6	1.0405	4.89

AMOUNT OF DRY ACID IN SULPHURIC ACID—*Continued.*

SO ₃ HO	Specific gravity.	SO ₃
5	1.0336	4.08
4	1.0268	3.26
3	1.0206	2.45
2	1.0140	1.63
1	1.0074	0.82

In this table there is opposite a list of different densities, the quantity of dry acid per cent., either dry or monohydrated. To bring the degrees of TWADDELL's hydrometer to those of the real specific gravity, it is only necessary to multiply the first by five, and add one thousand; thus, supposing a sample of vitriol to stand 150° on TWADDELL's hydrometer, multiply the 150° by 5°, and one has 750°; to this add 1000°, and the specific gravity, 1.750° is obtained. Now, to ascertain the amount of real sulphuric acid in this sample, it is only necessary to run through the table and find the density 1.750°, or the nearest approach to it, which in this case is 1.746°. It will be found then that the sample would contain eighty-three per cent. of the monohydrated acid, or 67.68 per cent. of dry acid.

This method of arriving at the value of a sample, though very convenient, is liable to error; for instance, the sample might contain foreign matter dissolved in it; this would augment the density, and cause it to appear of more value than it really is. A slight change of temperature also will alter the density considerably. The following table, the production of Mr. PARKER, shows the gradual lowering of the density as the temperature increases, so that, even though the sample may be free from foreign bodies, error may creep in. From this table it is evident, that the density of all samples of vitriol should be taken, as in the case of Dr. URE's table, at as near as possible 60°.

PARKER'S TABLE OF VARIATIONS IN DENSITY OF CONCENTRATED SULPHURIC ACID THROUGH CHANGE OF TEMPERATURE.

Temperature Fahrenheit.	Density.
30°	1.8593
32	1.8563
36	1.8546
38	1.8532
40	1.8527
42	1.8520
44	1.8522
46	1.8519
48	1.8517
52	1.8511
56	1.8500
60	1.8468
63	1.8449
68	1.8435
70	1.8430
74	1.8413
80	1.8381
84	1.8343

Again, when the density of a sample is high, it is difficult to estimate it with sufficient accuracy. If one examine Dr. URE's table, he will find that acid of 1.8439 specific gravity contains ninety-seven per cent. of monohydrated acid, while the density of the monohydrated acid itself is but 1.8485—thus the slight difference of .0046, or rather less than one degree on the hydrometer, equals three per cent. To obviate this, Dr. DALTON proposed that the boiling point should be taken as the guide, instead of the specific gravity, inasmuch as it permits a range of ten or twelve degrees for one per cent. of real acid. For this purpose he drew up the following table:—

DR. DALTON'S TABLE OF BOILING POINTS OF SULPHURIC ACID AT DIFFERENT STRENGTHS.

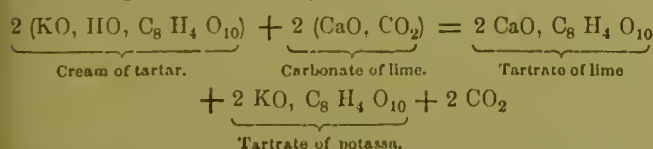
Specific gravity.	Dry acid per cent.	Boiling point.
1.850	81	620°
1.849	80	605
1.848	79	590
1.847	78	575
1.845	77	560
1.842	76	545
1.838	75	530
1.833	74	515
1.827	73	501
1.819	72	487
1.810	71	473
1.801	70	460
1.791	69	447
1.780	68	435
1.769	67	422
1.757	66	410
1.744	65	400
1.730	64	391
1.715	63	382
1.699	62	374
1.684	61	367
1.670	60	360
1.650	58.6	350
1.520	50	290
1.408	40	260
1.300	30	240
1.200	20	224
1.100	10	218

In addition to these methods, there may be mentioned that of testing the value of vitriol by an acidimetric process, with a standard solution of alkali.

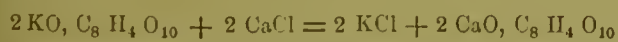
Mr. PETER HART, of Manchester, kindly supplied some valuable information which the Editor has incorporated in this monograph.

TARTARIC ACID— $2\text{HO}, \text{C}_8\text{H}_4\text{O}_{10}$ —*Acide tartarique*, French, *Weinsteinsäure*, German—was first obtained in a separate state by SCHEELE in 1770. It is found partly free, partly combined with bases in many plants. It exists most largely in grape-juice, but it is met with also in tamarinds, and the berry of the mountain ash; in madder, potatoes, cucumbers, quassia, squills; in mulberries, pine apples, *et cetera*.

Preparation.—In order to prepare the acid, four parts of crude tartar—*argol*—are suspended in boiling water, and one part of chalk added. As soon as the effervescence entirely ceases, and the liquid no longer reddens litmus, the tartrate of lime is allowed to settle at the bottom, and the clear tartrate of potassa decanted. The change which takes place, is as follows:—

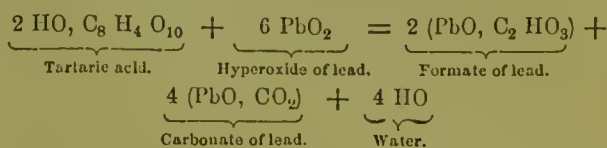


The dissolved tartrate of potash may be further decomposed by chloride of calcium: thus—

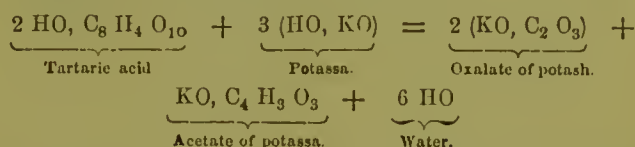


The well-washed precipitates are digested with sulphuric acid diluted with ten parts of water, five parts of the tartar employed requiring three parts of the acid. Sulphate of lime is formed, and tartaric acid set free. On evaporating the filtered solution in leaden vessels to the consistence of sirup, tartaric acid crystallizes in large, transparent, colorless, oblique rhombic prisms of agreeable sour taste, and specific gravity 1.75; is readily soluble in water and alcohol; unalterable in air. When greatly heated, the crystals become strongly electrical.

Boiled with nitric acid, tartaric acid is decomposed into acetic, oxalic, and saccharic acids. Boiled with hyperoxide of lead, it becomes oxidized and changed into formate of lead, water, and carbonate of lead, thus—



If heated with alkalis, a mixed oxalate and acetate results, with evolution of water, thus—



Mixed with spongy platinum and heated in a stream of oxygen, tartaric acid is at 482° completely resolved into carbonic acid and water.

The action of heat upon tartaric is as instructive as it is remarkable.

It melts between 338° and 356°, and without losing weight is changed into a mixture of two acids—metamerie with tartaric acid.

METATARTARIC ACID— $\text{C}_8\text{H}_6\text{O}_{12}$; or $2\text{HO}, \text{C}_8\text{H}_4\text{O}_{10}$ —forms a transparent vitreous mass. It is bibasic, but its salts are more soluble than the corresponding ones of tartaric acid.

ISOTARTARIC ACID— $\text{HO}, \text{C}_8\text{H}_5\text{O}_{11}$ —is monobasic. Its salts are isomeric with the bitartrates, but very much more soluble. Solutions of isotartrates as well as of metatartrates are changed by boiling into tartrates.

If tartaric acid be heated to 374° it fuses: two equivalents lose one equivalent of water and become changed into an acid, called by FRÉMY, **TARTRALIC ACID**— $3\text{HO}, \text{C}_{16}\text{H}_8\text{O}_{20}$.

If the heat be still longer continued tartaric acid loses half its basic water and becomes **TARTRELIC ACID**— $2\text{HO}, \text{C}_{16}\text{H}_8\text{O}_{10}$.

Most probably both tartralie and tartrelie acids are mere combinations of anhydrous tartaric acid with varied proportions of crystallized tartaric acid.

If the heat—374°—be carefully maintained for yet a longer time, **ANHYDROUS TARTARIC ACID** or **TARTARIC ANHYDRIDE** remains in form of a white, porous mass insoluble in water. Adherent tartrelie acid is removed by washing with water till the wash liquor no longer reddens litmus. By contact with cold water for a few hours anhydrous tartaric acid resumes its basic water.

Small quantities of tartaric acid are completely decomposed in an oil-bath at 512°, leaving only a slight carbonaceous residue.

Tartaric acid is much used by dyers and calico-printers for the removal of certain mordants from portions of the cloth. It is also used in preparing effervescing draughts. In the blood, tartrates are changed into carbonates.

Aqueous solutions of tartaric acid, especially when hot, exercise right-handed rotation upon polarized rays of light—the angle of deviation corresponds to the quantity of acid traversed by the ray.

Tartaric acid is *bibasic*; its salts are tartrates.

BITARTRATE OF POTASSA— $\text{KO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —is the *cream of tartar* or *argol* of commerce, and is obtained chiefly as an incrustation from the inside of wine casks. It crystallizes in hard, opaque, oblique rhombic prisms, of snowy whiteness when pure, and of sour taste; soluble in one hundred and eighty parts of cold and six of boiling water; in alcohol nearly insoluble. Heated to redness in close vessels, a mixture of carbonate of potassa and charcoal results—much used as *black flux*. Calcined with its own weight of nitre, *white flux*, or carbonate of potash, is obtained.

NEUTRAL TARTRATE OF POTASSA— $2 \text{KO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —by slow evaporation in transparent, colorless prisms, somewhat deliquescent, and very soluble.

BITARTRATE OF SODA— $\text{NaO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 2 \text{HO}$ —in transparent, colorless, right rhombic prisms, from a hot solution of the neutral salt, mixed with half its weight of tartaric acid.

NEUTRAL TARTRATE OF SODA— $2 \text{NaO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 4 \text{HO}$ —soluble in five of cold and half their weight of boiling water. In transparent, colorless, right rhombic prisms.

NEUTRAL TARTRATE OF POTASSA AND SODA— $\text{KO}, \text{NaO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 8 \text{HO}$ —is *Rochelle salt*, obtained by neutralizing cream of tartar with carbonate of soda. In large, transparent, colorless, right rhombic prisms, soluble in 2.62 parts of water at 42° . The salt is medicinal.

BITARTRATE OF LITHIA— $\text{LO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 3 \text{HO}$ —in small crystals, very soluble in water.

NEUTRAL TARTRATE OF LITHIA— $2 \text{LO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —white, opaque, deliquescent.

BITARTRATE OF AMMONIA— $\text{NH}_4\text{O}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —in delicate needles, but little soluble in water. The crystals are in form of oblique rhombic prisms.

NEUTRAL TARTRATE OF AMMONIA— $2 \text{NH}_4\text{O}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —in oblique prisms, readily soluble, and with a taste like that of nitre.

NEUTRAL TARTRATE OF POTASH AND AMMONIA— $\text{KO}, \text{NH}_4\text{O}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —in transparent, colorless prisms, isomorphous with neutral tartrate of potash.

NEUTRAL TARTRATE OF BARYTA— $2 \text{BaO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —a crystalline powder, soluble in eight hundred parts of cold water.

NEUTRAL TARTRATE OF STRONTIA— $2 \text{SrO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 8 \text{HO}$ —soluble in one hundred and forty-seven parts of water at 60° .

BITARTRATE OF LIME— $\text{CaO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —in the fruit of *Rhus typhinum*, in crystals, sparingly soluble in water.

NEUTRAL TARTRATE OF LIME— $2 \text{CaO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —occurs in grapes, and mixed with crude tartar; also in senna leaves. Neutral tartrate of potash forms, with chloride of calcium, a crystalline precipitate—it is the salt obtained in making tartaric acid. Crystals, right rhombic prisms with octohedral summits; soluble in twelve hundred parts of cold water.

BITARTRATE OF LIME— $\text{CaO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —in the fruit of *Rhus typhinum*. The crystals dissolve in one hundred and forty parts of water and redden litmus.

NEUTRAL TARTRATE OF MAGNESIA— $2 \text{MgO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 8 \text{HO}$ —obtained by digesting excess of magnesia alba in dilute tartaric acid. Crystalline crusts

soluble in one hundred and twenty-two parts of cold water. Like tartrate of lime, the residue by ignition is pyrophoric.

BITARTRATE OF MAGNESIA— $\text{MgO}, \text{HO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —when excess of acid is employed. Six-sided prisms soluble in fifty-two parts of cold water.

TARTRATE OF ALUMINA occurs in *Lycopodium clavatum*. Very soluble.

TARTRATE OF LEAD— $2 \text{PbO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —by precipitating neutral acetate of lead with tartaric acid. A white crystalline powder, almost insoluble in water.

PROTOTARTRATE OF IRON is made from iron filings and dilute tartaric acid, with exclusion of air. A white powder requiring four hundred and twenty-six parts of cold water for solution. It is said to contain thirty per cent. of water.

PERTARTRATE OF IRON, by dissolving the freshly prepared hydrated peroxide of iron in solution of tartaric acid. Its solution is not precipitated by alkalis.

POTASSO-TARTRATE OF IRON— $\text{KO}, \text{Fe}_2 \text{O}_3, \text{C}_8 \text{H}_4 \text{O}_{10}$ —is an important medicinal salt. It is obtained by digesting the hydrated peroxide of iron with water, and bitartrate of potassa at 125° for twenty-four to thirty-six hours, and evaporating the residue on plates. In lustrous scales of dark brown color.

AMMONIO-TARTRATE OF IRON— $\text{NH}_3, \text{Fe}_2 \text{O}_3, \text{C}_8 \text{H}_4 \text{O}_{10}, 4 \text{HO}$. Made like the previous salt, with substitution of bitartrate of ammonia. It is quite stable in composition when its solution is boiled.

TARTRATE OF COPPER— $2 \text{CuO}, \text{C}_8 \text{H}_4 \text{O}_{10}, 6 \text{HO}$ —by precipitation of acetate of copper with tartaric acid. A very light blue powder, soluble in one thousand seven hundred parts of cold water.

POTASSO-TARTRATE OF COPPER— $\text{KO}, \text{CuO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —by boiling oxide of copper in solution of cream of tartar. Crystals dark blue; very soluble.

TARTRATE OF SILVER— $2 \text{AgO}, \text{C}_8 \text{H}_4 \text{O}_{10}$ —by mixing neutral tartrate of potash or Rochelle salt with nitrate of silver. A white, crystalline, lustrous powder: gently heated, spongy silver remains, with evolution of pyrotartaric and carbonic acids.

POTASSO-TARTRATE OF ANTIMONY— $\text{KO}, \text{SbO}_3, \text{C}_8 \text{H}_4 \text{O}_{10}, \text{HO}$ —is extensively used in medicine under the name of *tartar emetic*. Three parts of oxide of antimony are made into a thin paste with water, and mixed with four parts of bitartrate of potassa. The mixture is digested for several hours, and then boiled with eight parts of water. The boiling-hot solution is filtered and allowed to crystallize. Transparent or opaque, colorless, shining rhombic octahedra, of metallic taste. It is soluble in fifteen parts of cold and two of boiling water. In small doses it is an emetic; in larger doses it is a poison.

Of the heavy metals, iron is the only one which precipitates antimony completely from the aqueous solution of tartar emetic. Hydrochloric, nitric, and sulphuric acids precipitate a basic hydrochlorate, nitrate, and sulphate of the oxide of antimony.

There are several other antimonial tartrates, the place of potassa being supplied by soda, ammonia, lead oxide, and silver oxide. A compound similar to tartar emetic may be formed with arsenious acid— $(\text{KO}, \text{AsO}_3, \text{C}_8 \text{H}_4 \text{O}_{10})$.

TIN.—*Etain*, French; *zinn*, German; *stannum*, Latin.—Tin is the *Jupiter* of the alchemists. It is one of the metals which were known to the ancients, and is evidently of high antiquity, although, in all probability, gold, silver, copper, and iron were known much sooner. It is supposed by some that the original Hebrew term *bedil* of Holy Writ indicates this metal; but others infer that a compound or mixture resulting, perhaps, from the purification of gold and silver possessing an inferior value, was meant by it. Under the impression that the word above mentioned denoted tin, the Greek translators of the scriptures rendered it *χασσιτερος*, by which term the classic writers of profane history describe tin, after all doubt had been removed as to its identity. BECKMAN discusses the question whether the *stannum* of the Latins and the *χασσιτερος* of the Greeks was really the metal which forms the subject of the present article; and whilst he leaves the point undecided, advances various arguments to show that a rich alloy of silver and lead was frequently, if not always, the substance indicated by the foregoing titles.

Whatever may have been the nature of such alloys, it is certain, from the writings of DIOSCORIDES, DIODORUS, PLINY, and others, as well as from Celtic records, that tin was known at a very early period. It is recorded that between 1040 and 1030 before the Christian era, the Phœnicians had discovered that part of Britain known at present as Cornwall and Devon, and instituted searches for minerals and metals therein; and the active exportation of the metals—principally tin—led to the adoption of the title *Breotan*—red or burning fires and land—for the mainland, from the circumstance of large fires being kept burning on all the bold heights of the country to serve as beacons for the mariners along the dangerous coast; of which words Britain is but a slight modification. The metal tin was called in the dialect of the people of Phœnicia *stān*, whence the *stannum* of the Romans; from this root likewise has been derived the title *Stanneries*, which is still applied in Cornwall to the districts where tin is produced.

That the quantity of tin extracted from the British mines was considerable, is very evident even from the account of the Greek writers already alluded to; thus DIODORUS, in the second chapter of his fifth book, says—The inhabitants of that part of Breo-tan—Britain—called Bolerion—supposed to be the Land's-end, but actually a corruption of *Bal-erig*, which means the country of the *Erians* or *Iberians*, of which it is an abbreviation—excel in their hospitality; and also, from their converse with merchants, they are more civilized and courteous to strangers. These are the people who make the tin, which, with a great deal of care and labor, they dig out of the ground which is rocky; but it has in it earthy veins, the produce of which is brought down, melted, and purified. Then when they have cast it into the form of cubes, they carry it to an island adjoining to Britain called Iktis. During the recess of the tide the intervening space is left dry, and the tin is carried to the island in carts; and it is something peculiar that happens to the islands in those parts lying between Europe and Britain, for at full tide, the passage being overflowed, they appear islands; but when the

sea returns, a large space is left dry, and they are seen as peninsulæ. From this the tin is transported to Gaul, through which it is conveyed on horseback in about thirty days to the mouth of the river Rhone.—*Diodorus*.

The island above alluded to will be at once recognized as one of the Scillies, and its Greek name was probably derived from its being made a fishing-station by the Phœnicians.

Of the mode of operations by which the tin was extracted, or the mines worked in those days, no record is left; but from the remains which have been discovered, it is conjectured that the methods adopted were of the rudest description. By whatever means the mining and metallurgy of tin were prosecuted in Cornwall and Devon up to the period of the Norman conquest, it is certain that after that event they received a great impetus, so that the chief part of the revenues of the Earls of Cornwall was derived from it. King John gave a charter to the Cornish tin mines in 1201; another was granted them in 1305 by Edward I., and the stannery laws were instituted in his reign. These laws are still extant, and partly in force; but want of space forbids a full account of them here. Previous to the thirteenth century England enjoyed a monopoly of the tin trade; but in that age rich veins of tin ore were discovered in Misnia and Bohemia; and about the year 1250 the English trade was much reduced by the low price at which the Germans were able to sell their tin. At present tin is found in several places, and mines of it are wrought in Bohemia, Saxony, and Austria; in Galicia, on the borders of Portugal; at Piriac, in the *Loire inférieure*; and at Vaulry, in the department Haute Vienne in France; but the mines of French localities are of very little importance. Large quantities of tin ore occur in the Siberian mining district of Nertschinsk, and it is found in Dalecarlia in Sweden; but the richest deposits that have hitherto been found are those in the province of Tenasserim on the east side of the Gulf of Martaban in the Malayan peninsula; these have been worked for many centuries, and considerable quantities are still obtained. In the early part of the last century—1710—large quantities of very pure ore of tin were discovered in the island of Banca, whence as much as three thousand five hundred tons of the metal have some years been abstracted. Minerals of tin exist also in Brazil, in Mexico and Chili, in South America, in the United States, and Australia. The tin mining districts of Cornwall and Devonshire are three in number; namely, that included in the South-west of Cornwall beyond Truro, the neighborhood of St. Austell, and of Tavistock in Devonshire. The chief tin mines in these districts are Wheal Vor, near Helston; Polberrow, near St. Agnes; Polgooth, near St. Austell; Drake Walls, near Tavistock, on the Cornish side of the Tamar; and Birch Tor, also near Tavistock, but on the Eastern side in Devonshire. Ores of tin are found in all the localities mentioned, either in the form of regular lodes or veins disseminated in granite and in felspar—porphyry or elvan—and in alluvial formations on the slopes of hills, or in the valleys. In the former instances, the veins frequently cross one another either horizontally or in their perpendicular descent; occasionally they ramify through the rock in all directions,

producing at the point of intersection masses of ore called by the Germans *stockwerk*, such as the Altenberg mine in Saxony. In the other instance of the occurrence of tin ore, namely, in alluvial deposits, it is usually called *stream tin*, as well from the nature of the deposit, as from the fact that in these cases the workings are generally in the course of rivulets or streams. It is found either in a pulverized sandy state, in separate stones, called *shodes* in Cornwall, or in a continued course of stones, which are sometimes found together in large numbers, and at depths varying from one to fifty feet. The course of these deposits is called a stream; but they have little regularity, varying in their breadth, and are scattered over the entire extent of the moor or valley in which they are found. *Wood tin*, the name given to pebbles of ore having a woody appearance, though now rather scarce, was formerly found in some of the stream-works of Cornwall.

MINERALS OF TIN.—Tin is found almost invariably in the form of binoxide of tin or tin-stone, and in some instances associated with iron and copper pyrites, forming what is called tin pyrites or bell-metal ore, but the quantity so existing is very small.

BINOXIDE OF TIN—*Cassiterite*; *tin-stone*; *zinnstein*.—This ore of tin, from which almost the whole of the metal is smelted, is found, as already mentioned, in different states of aggregation. It is characterized by a high gravity, averaging 6·3 to 7·1, adamantine lustre, and color varying from a brown or black to various shades of red, yellow, grey, and white. In crystalline shape it belongs to the right prismatic system, the crystals being twins, with some of the faces uneven, and others striated parallel to their intersections with each other. The crystals have but a very imperfect cleavage, their fracture is imperfectly conchoidal and their streak grey, and sometimes brown. Heated before the blowpipe, oxide of tin remains infusible *per se*; with soda in the reducing flame it affords small globules of metal. Acids do not exert a solvent action upon it, and therefore it cannot be dissolved till after its fusion with alkalis. In its pure state binoxide of tin contains—

	Atomic weight.	Centesimally.
1 Eq. of tin,	59	78·66
2 Eqs. of oxygen,	16	21·34
	75	100·00

Samples of the ore have been analyzed, and the results are stated thus—

	From Altonon In Cornwall, by Klaproth.	From Schlacken- wald, by Klaproth.	From Finbo, near Fahlun, by Berzelius.
Oxide of tin,	98·93	99·28	93·6
Red oxide of iron,	0·32	0·72	1·4
Silica,	0·75	—	—
Columbic acid,	—	—	2·4
Binoxide of manganese	—	—	0·8
	100·00	100·00	98·2

This ore is found in the various localities already referred to, accompanied with quartz, mica, fluor spar, apatite, topaz, tourmaline, wolfram, heavyspar, mispickel in the lode; and in the alluvial beds of valleys and plains.

TIN PYRITES—*stannin*; *zinnkies*.—This ore of tin occurs in a few of the Cornish mines, such as those

of Huel Rock in St. Agnes, and some of the granite veins in St. Michael's Mount; also at Zinnwald in Bohemia. Its crystalline form is cubic; the cleavage of the crystals is imperfect, the fracture uneven and conchoidal, the lustre metallic, with a steel-grey, inclining to bronze-yellow color, and a black streak. The specific gravity is 4·3 to 4·51.

Before the blowpipe on charcoal it melts in a strong heat, turns white on the surface, and deposits a fixed sublimate of binoxide of tin round the assay. After roasting, it affords, with the usual fluxes, the peculiar reactions of iron and copper, and a brittle globule of the latter metal on fluxing with soda and borax. Nitric acid decomposes it, dissolving the iron and copper, and leaving a deposit of sulphur and of binoxide of tin. The following analyses indicate the composition of a few samples of this ore; samples A and B from Huel Rock; C from St. Michael's Mount, and D from Zinnwald:—

	Klaproth.		Johnston.	Rammelsberg
	A	B	C	D
Copper,	30·00	29·69	23·55	25·31
Iron,	12·00	12·57	4·79	6·80
Zinc,	—	1·79	10·11	6·43
Tin,	26·50	25·81	31·62	25·84
Lead,	—	—	—	0·41
Sulphur,	30·50	29·95	29·93	29·23
Loss,	1·00	0·19	—	0·72
	100·00	100·00	100·00	100·00

PREPARATION OF TIN.—The reduction of the ore is effected by roasting and smelting, in a manner similar to that which will be described further on, and the button so obtained is then treated in the following manner, to separate the metal from the arsenic, antimony, bismuth, zinc, lead, iron, and copper, one or more of which it may contain; or ordinary commercial tin may be taken for this purpose.

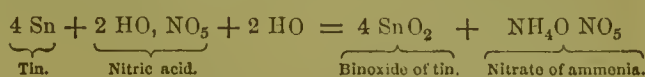
In either case the crude metal is treated with an excess of hydrochloric acid, when the tin, zinc, bismuth, copper, and iron are dissolved, whilst the arsenic and antimony will be separated; the former volatilized in the form of terhydride of arsenic, and the latter partly deposited as a black powder in the liquid, and partly dispelled as antimonide of hydrogen. The solution is filtered, and the liquid concentrated at a boiling temperature, and strong nitric acid in excess added, after which the evaporation is continued to dryness. The tin is thus obtained in the state of binoxide, which should be treated with a little hydrochloric acid, then filtered, washed thoroughly, and dried, mixed with charcoal, and reduced at a white heat in a charcoal-lined crucible.

Properties.—Tin is a white metal, having a metallic lustre, approximating to that of silver; it is softer than gold, but harder than lead, and has a specific gravity of 7·291. It is very malleable, so much so that it can be rolled into sheets of not more than the one-thousandth of an inch in thickness, but wanting ductility and tenacity to any useful degree. A wire of the metal, 0·7 of an inch in diameter, will sustain only thirty-four and a half pounds weight. Tin melts at 442°, and contracts slightly on cooling; at a strong red heat it emits white fumes, but the tension of its vapor is

very feeble, and therefore little loss of metal is sustained. The metal exhibits a great tendency to crystallize when a mass of it is melted in a covered crucible, and allowed to cool very slowly; if before the bulk has solidified the fluid portion be poured off, the hardened part remaining in the vessel will be found crystallized in rhombic plates, according to PAJOT; and in octagonal needles, according to BROOKE. This tendency to crystallize is readily exhibited by dissolving the exterior coating of a plate of the metal by means of moderately dilute aqua-regia, and then washing off the acid with water. The surface will then exhibit a mottled appearance, owing to the irregular reflection of the fern-like crystals which the action of the acid reveals. Various pretty designs are in this way formed on the surface of moderately thick tinned plates; and the French, who practise the process for decorating snuff-boxes, *et cetera*, call it *moiré métallique*. It is to the crystalline arrangement of the particles of the metal that the crackling sound which a bar of it emits on being bent backward and forward is due, the decrepitation being produced by the displacement of the small crystals of which the bar is composed. By repeatedly inducing this friction an amount of caloric is developed, which can be readily detected by a sensible calorimeter.

Tin retains its brilliancy for a considerable time when exposed to the air; when heated in the air to the melting point, however, it is immediately covered with a film of oxide of tin; and if the heat be increased, the oxidation of the metal becomes so rapid as to induce ignition. In both instances binoxide of tin results. The same change takes place when steam is passed over a bath of the metal heated to redness out of contact of air; for the metal abstracts the oxygen of the water, and sets free the hydrogen. Tin combines with most of the metalloids, producing generally two orders of combination, distinguished by the terms proto or stannous, and binary or stannic, compounds of such elements with the metal. The combination with many of these, as with sulphur, bromine, iodine, chlorine, *et cetera*, is so intense that, at a slightly elevated temperature the metal enters into active combustion, whilst the stannic salts of these radicals are produced. Acids have likewise a well-marked action upon it; for instance, hydrochloric acid, at the ordinary temperature, slowly dissolves it, with evolution of hydrogen; at a boiling temperature the action is much more active; in both reactions the stannous chloride is formed. Dilute sulphuric acid, with the aid of heat, converts it slowly into a sulphate of the protoxide, and liberates hydrogen; the concentrated acid has little or no effect upon it in the cold, but if the liquid be heated to the boiling point, it rapidly attacks the metal, sulphurous acid being liberated. Slips of bright tin-foil, immersed in concentrated nitric acid, experience no change, however long they may be

retained in it; but if the acid be diluted with water, the action becomes violent, owing to the rapid conversion of the metal to a binoxide of modified properties, known as metastannic acid, and the evolution of binoxide of nitrogen. If the nitric acid be previously diluted, no nitrous fumes are given off during the oxidation of the metal, but nitrate of ammonia is formed, thus—



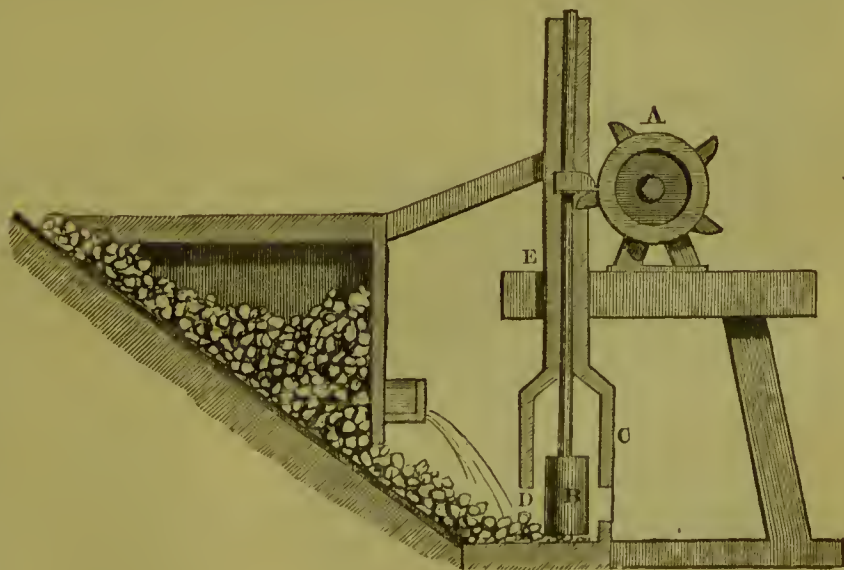
The fixed caustic alkalies dissolve tin, and produce with it a compound in which the combination of this metal takes the character of a salt radical; in this case water is decomposed and its oxygen is assimilated by the tin, whilst the hydrogen is given off.

The symbol for tin is Sn; its equivalent number 59.

METALLURGY OF TIN—Preparation or Dressing of the Ore.—In preparing ore of tin for the smelter, much pains are taken for the separation of all earthy matters and metallic substances that would reduce the percentage yield of the ore, or injure the quality of the tin when smelted. The order in which this dressing is performed is much the same as when copper ores are under treatment—namely, *cleaning* and *sorting* of the ore, *stamping* and *washing*, and, finally, *calcination* and *washing*.

Sorting the Ore.—This operation is commenced on the surface by washing away the clay and light impurities from the ore by a stream of water, and breaking or *spalling* the stones containing the ore, and separating the whole into heaps of different qualities and classes, according to the nature of the gangue, or the other minerals accompanying the tin; thus ores containing copper and iron pyrites are classed differently from such as contain only earthy matters, and such as contain tungsten are set aside by themselves to be submitted to a special treatment. The richest and

Fig. 599.



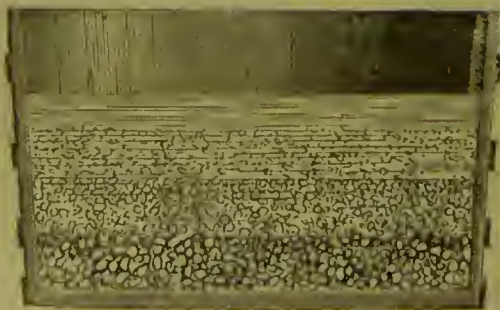
purest lumps are placed together in heaps on the dressing floor, and are called *best work*; the second quality, though less rich than the preceding, are

nevertheless remunerative; and the third division consists of matter that is very poor in, if not wholly without, ore.

The several heaps of ore are further reduced by the stamping mill to a fine powder. This *machine* is shown in section in Fig. 599. It consists of a wooden shaft, connected with a water-wheel or steam-engine, in which are arranged a number of cams that catch upon the lifting arms of a series of pestles heavily shod with iron, and secured in a strong wooden box lined with iron to prevent the dispersion in all directions of the ore by the strokes of the pestles or stamps. In the figure, A indicates the revolving shaft with the cams, B the pestle, and C the box confining them, D the ore to be crushed, and E a sluice which supplies a stream of water that carries off the reduced ore to the tanks along narrow inclined planes. Four stamping heads, averaging two and a half to three and a half hundredweight each, are worked in each box, and in the following order:—The pestle to the left of the spectator, supposed to be standing in front, first; the extreme right second; the right middle one third; and the left middle last—and each pestle is so lifted that the strokes follow in succession. The revolving shaft makes about twenty revolutions per minute, and the ore which enters the box receives from one hundred and sixty strokes to double this number to reduce it. The stream of water, entering the box from E, conveys the reduced ore, aided by the force of the pestles, through gratings at the ends and sides of the box to the inclined plane or cistern already mentioned. Here the ore, in consequence of its gravity varying in the ratio of its contents of metal, arranges itself into three kinds—the heaviest, and therefore the richest, resting on the upper part; a less rich ore in the middle; and the poorest or gangue parts—the tailings—at the lowest part. Very fine portions of the ore are carried off by the water in suspension to the slime pits, where it settles to the bottom, to be occasionally collected. The richest portion of the ore on the inclined plane is removed to the rectangular *buddle*, where it is washed under a regular stream of water, the ore being kept by a brush spread equally over the floor of the buddle. In this way the material is further purified, the richer ore remaining on the upper half of the table, and a poorer product on the lower half.

The richer ore is further purified in the *kieve*, or tos-

Fig. 600.



sing tub—Fig. 600. It consists simply of a stout wooden vat, well bound with iron hoops, having a capacity of a hundred gallons or more. A quantity of the purer

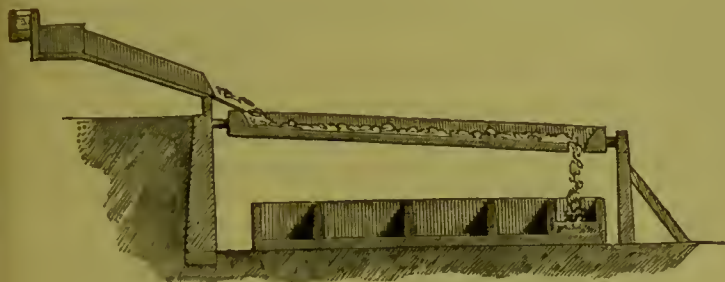
ore, from the buddle in the preceding instance, together with a quantity of water, is thrown into the tub and stirred well up with a shovel for a few minutes, and then allowed to rest, while to expedite the subsidence of the ore, the workman strikes the tub all round with a hammer. Here, again, a further separation of the ore takes place, according to the order of its gravity, the richer kinds being nearer the bottom of the tub, and forming distinct layers, as shown in the figure. The top layer is thrown away as being of little value, or is reserved for further washing in the circular buddle with other portions of poor ore; the second is submitted to another washing; and the lower layer is fit for the smelting furnace or the roaster, if it be pyritic, and is called *tin wits*.

The matter on the middle of the inclined plane or cistern adjoining the stamping mill is delivered into a wooden trough placed over the cistern, and washed by a small stream of water direct into the circular buddle, where the washing of ore is effected in larger quantity, and at less expense than in washing the rich ore as it becomes separated. Several of these circular buddles are required, and the lower layer of the deposit in one is conveyed by a trough to the next, and there washed. In this way the richer parts are removed from the poorer tailings; and when they arrive at the proper standard they are removed, and their cleansing finished on the rectangular buddle and tossing tub, as described. The contents of the slime pits are purified, first, by what is known as the *trunking process*, and secondly, on the *racking table*. The trunking box consists of a long sloping cistern, with a division near its upper end, forming a small quadrangular vessel, in which the ore, slime, and water are delivered. The contents of this small cistern are agitated by the slow movement of a paddle placed in it, and thus portions of slime and water are thrown out into the sloping trunk at each stroke. As it flows down this incline the heavier ore first separates, and continues to deposit, according to its density, towards the end of the trunk, where, however, the matter collected is of little worth. When enough of the mud is thus treated to fill the long cistern, the admission of more of the sludge is prevented, and the higher portion of the deposit is transferred to the *racking tables*, whilst the other portion is again submitted to the preceding trunking process. The racking table, shown in Fig. 601, is a long wooden table, set at an incline of one in sixteen, and having shallow bevelled flanges at the sides and ends to serve as a frame for it, and supported by centre pivots on a wooden framework about three feet high. At the head of the table is fixed the sloping board, hinged to it with leather, and upon this the mixture of ore and water is delivered, and a number of boxes, generally three, are fixed beneath it to receive the different qualities of the washed product.

About twelve or fifteen pounds of the selected stuff from the trunk boxes are placed on the fixed head and washed over the hinge board to the table. It is equally distributed over the board with the aid of a rake or brush, when the water sweeps along the lighter portions, and carries the worthless matter through a

narrow slit at the bottom of the table into a gutter. The selected and rich deposit on the table is washed out into the receptacles beneath it by inclining the latter to one side, and a fresh quantity operated upon

Fig. 601.



as before. The contents of the first, second, and third box are washed again on the rack once, twice, or thrice, as it is deemed necessary, before the product of the first vessel is sent to the tossing tub.

Stream tin is dressed by a similar course of operations as the foregoing, only that the ore is first treated in a large trunking box, where the workmen separate by a rake the larger from the smaller particles of ore. After this, the divisions of ore are submitted to a picking, stamping, and washing operation, mostly like that detailed above. With stream tin these processes serve to produce a very pure ore, devoid of most of its earthy components, and ready for the smelter; but when the tin is found in lodes, associated with copper and iron pyrites, the dressing course with simple washings is insufficient to remove the sulphurous compounds, and with which the ore cannot be smelted.

To remove them, the ore from the tossing tub—the *tin witts*—is conveyed to the burning house, and roasted in reverberatory furnaces, or in a kind of roaster called from its inventor BRUNTON'S calciner. The reverberatories are of the usual form, having a bed about nine feet long, five feet wide in the middle, and four feet at the back part, wherein is situated the working door. The charge, amounting to ten or twelve hundredweight of ore, is let down upon the bed through a hopper in the arch, and when roasted it is drawn out to an arched space beneath the bed by a small aperture inside the working door in the latter. The temperature supplied should not exceed a dull red heat, such as will be capable of dispelling the arsenic and sulphur without fusing the sulphurous compounds. Frequent rabbling of the ore on the bed of the furnace expedites the separation of the sulphur and arsenic; but, under all the attentions given, the time for each charge averages, according to the amount of impurities, from eight to twelve hours. The arsenical and sulphurous vapors pass from the furnace into a wide flue, which is divided into a series of compartments or chambers of varied dimensions, for the purpose of arresting the arsenic, and leading to a low chimney usually erected on some adjoining and commanding eminence.

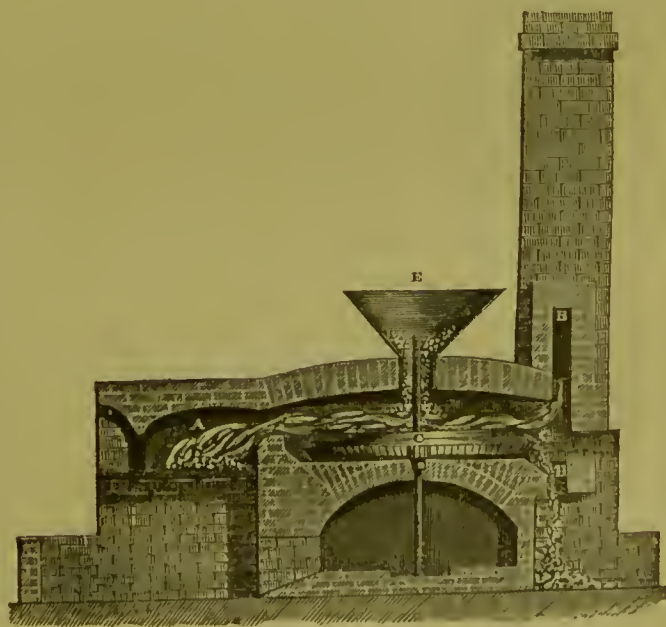
BRUNTON'S calciner is shown in Fig. 602. It is a circular cast-iron table fixed on a stout central shaft,

placed in proper bearings beneath the furnace, so as to permit its turning slowly with the table, C, which is set in motion by a small pinion gearing into a toothed wheel fastened to its under side. This table is fixed beneath the dome of a reverberatory furnace, having a hopper, E, for retaining the ore to be calcined, and in which the upper end of the central shaft turns and distributes the ore on the plate in a continuous stream. The fire is at A, and the products of its combustion pass over the ore to the flue, B, leading to the chimney. Owing to the revolution of the bed of the furnace the ore is kept constantly turned and moved till it travels to the circumference whence it is ejected through the apertures, H, into the receptacle or *wrinkle*, G, in the same ratio that it is supplied from the hopper. Power is communicated to the gearing pinion by a water-wheel or

other means; and the rate at which the ore is to pass over the calciner is regulated by the quick or slow motion of this shaft. Much labor and fuel are said to be economized by the adoption of this system of roasting.

The roasting effects the conversion of the dense metallic sulphides into friable and light oxides, which, being of a less gravity than the tin ore that remains unaltered by the operation, can be readily separated by a proper system of washing. The several kinds of products from the preliminary dressing, such as jigged, fluran, smalls, slime, and roughs, are burned separately,

Fig. 602.



and each subjected afterwards to a particular treatment; thus the jigged parcels are simply jigged again on a copper sieve after the burning; the fluran is passed through the buddle and tic, and the finer divisions are submitted to more complicated processes, consisting of *buddling*, *tossing*, *packing*, and further washing of the residues from these operations on hair sieves, till finally

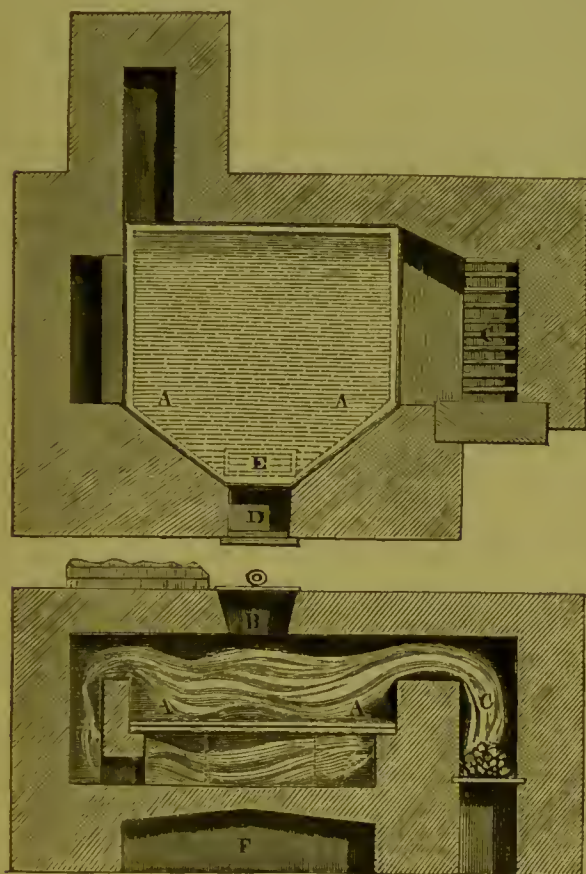
the tin crop remains as pure as possible. Numerous divisions of tin ores are made according to the quantity of the accompanying bodies and their nature, besides those already alluded to; and their dressing gives rise to several refuse matters, the purification of which necessitates a complication of operations, which are varied according to circumstances and the judgment of the superintendent of the mine. The *burned leavings* from the foregoing operations, containing more or less tin, are restamped with some silicious matter and rewashed; the crushing with the sand, *et cetera*, detaches from the particles of tin the earthy matters that were combined with them, and that rendered them specifically lighter in the preceding washings. They may now be readily separated by a stream of water in the trunking box or buddle, and the tin obtained.

Improvements in the Dressing of Tin Ore.—Several improved methods of purifying ores of tin have been suggested and practised during the last quarter of a century. The principal of these consist in the use of acids for the separation of the injurious matters from the tin ore, which remains unacted upon by them. By the use of hydrochloric and sulphuric acids the fragments of metallic iron from the tools of the miners, of oxides of iron, copper, *et cetera*, are dissolved and removed from the tin by simple washing, much more effectively, than could be done by any mechanical operation, however carefully performed. Acids have been in use for the dressing of tin ores since 1842, or earlier; muriatic acid being preferred where the impurity is iron and its oxide, and sulphuric acid for the separation of the copper existing in the roasted ore as oxide, which is afterwards thrown down from its solutions by metallic iron or zinc, and the sulphate of iron, or of zinc recovered. LONGMAID'S patent process of separating the sulphur from pyritic ores by fusing them with common salt, whereby the sulphur is converted into sulphate of soda, and the copper into the form of chloride, could be applied to the purification of tin ores containing the foregoing additional metals. Washing the roasted mass would remove the copper salt, and the sesquioxide of iron would be carried off in mechanical suspension, leaving the oxide of tin in a partially pure state behind. The preceding methods of treatment do not serve to purify ores of tin associated with *wolfram*—the double tungstate of iron and manganese—for this mineral has a density averaging 7.1 to 7.4, and therefore so closely approximating to that of tin that no amount of mechanical washing could part the two satisfactorily. Before the process for its purification was discovered, the tin obtained from this kind of ore was very inferior, and consequently the ores themselves were greatly depressed in value. By OXLAND'S method of removing the tungstic acid from them, however, they are so improved that first quality tin can be smelted from them, and necessarily with such purification their value has been correspondingly enhanced. The principle of OXLAND'S patent is that on fusing ores containing tungstates with alkaline salts, such as carbonates or sulphates of soda or potassa, the tungstic acid combines with the alkaline base, producing an alkaline tungstate, which may be dissolved out, and converted to useful purposes in calico-printing or painting, thus

returning as much if not more than the expense involved in the treatment. The tin ore, as finely dressed as possible, is mixed with as much soda ash or crude soda as will be sufficient to form an alkaline tungstate with the amount of tungstic acid which analysis shows the mineral contains. The mixture is then introduced into the bed of a reverberatory, and heated to low redness, which temperature is sufficient to induce the combination of the alkali and the metallic acid body. When the operation is finished, as observed by the color the mass assumes, and the consistency of a thick paste which it takes, it is raked out by an opening in the bed of the furnace into a receptacle beneath, whence it is taken and cast into vats filled with water, which dissolves out the tungstate of soda, leaving the other constituents of the ore untouched. By a judicious use of the water and a properly-constructed vat, the whole of the tungstate can be extracted with very few changes of water, and without diluting the solution to an inordinate degree. While this operation is progressing, the furnace is being charged with a further quantity of the mixture, which is spread out upon the sole, and left so with the furnace doors closed, till the alkali begins to melt and the mass emits a hissing sound, resulting from the expulsion of carbonic acid from the soda salt by the metallic acid. It is then slightly stirred; and when the preceding noise subsides, and the forementioned indications are observed, the roasted mass is ready for drawing. Latterly, instead of carbonate of soda, or crude soda, sulphate of soda or *salt cake* has been substituted, both on account of its cheapness compared with soda ash, and of its answering all the required purposes, in this respect, as well as the latter salt. Some skill and practical judgment are required, however, on the part of the furnaceman who has the control of the process, to insure success. The charge containing a quantity of sulphate corresponding to the tungsten in the ore, is put into the reverberatory—Fig. 603—through the workable opening, B. in the arch, and spread by the furnaceman upon the iron bed, A A, of the furnace through the working door, D. The bed is composed of two stout cast-iron plates fixed in the sides of the furnace, and supported near the centre by lines of brickwork; the space left by this arrangement between the plate and solid brickwork forming a flue for the smoke and waste gases of the fire to return under the sole, and thus assist in heating it. C is the fire which at the beginning of the operation should produce a highly carbonaceous flame, with the view of reducing the sulphate of soda to the state of protosulphide, to induce the decomposition of the tungsten and the combination of the acid. For the same purpose some small coal or charcoal is mixed with the charge, the more readily and efficiently to decompose the sulphuric acid of the soda salt. A dull red heat is maintained with all the available openings to the interior of the furnace closed, and a strong reducing flame, till the reduction of the sulphate is effected, occasionally stirring the mixture well till the phosphorescent appearance of the mass disappears. At this stage of the operation a bright oxidizing flame should be produced, to induce the further decomposition of the alkaline sulphide and the

formation of the soluble tungstate; after which it is raked out through the hitherto closed aperture, E, to the vault, F. This process has been carried out at the

Fig. 603.



Drake Wall Mine in Cornwall since 1850 with every success.

The solution of tungstate of soda obtained by the exhaustion of the fluxed ore with water, is concentrated in iron pans to the crystallizing point, and drawn off into crystallizing vessels, where it remains. In a few days the tungstate separates in beautiful crystals, and which, after slight washing and draining, are fit for market. On concentrating the mother liquors a further crop is obtained. After the ore is exhausted of its soluble salts it is transferred to the floor of the burning house, and the iron and manganese separated by washing or treatment with acids, according to the methods already detailed.

From a consideration of the several operations which ores of tin pass through from their coming to *grass*, as it is called, till they are ready for the smelter, it is supposed that fully a third or more of the quantity of tin originally in the ore is lost. Distributed as the tin must be in minute grains in the stony gangue, it is evident that the latter cannot be so thoroughly broken off from the tin as to leave it isolated, and thus in a state to separate in the several washings. Further, where the tin ore is to the whole of the matter mined as one to thirty or thirty-five, a good deal of tin must be rejected in the tailings of the first process which it has to undergo, *videlicet*, the *spalling* and picking;

and analysis of the refuse matters shows that they invariably contain quantities of tin, which loss must be entirely owing to the imperfect, or rather inadequate methods, adopted for disintegrating the ore, and the very slight difference in the low gravity of the gangue which the associated grains of tin ore must occasion, so that such ore will be entirely lost to the miner.

Modern researches show that the loss of tin in the dressing of poor ores is much greater than when richer products are operated upon, in which, however, it amounts to about twenty-five per cent. of the whole quantity. This great loss is attributed to the large amount of tailing stuff produced, and the large body of water made use of in the course of the working. Whilst the existing mode of tin dressing is practised, that loss can hardly be avoided, or at best but slightly lessened. To obtain the whole of the two to three per cent. of binoxide of tin in the tin stuff, the dressing must be based upon chemical rather than mechanical principles. Considering that the loss of tin at present sustained in dressing a hundred tons of stuff averages fully fifty to sixty pounds worth of tin, the recovery of this waste would afford a scope for a partial outlay by which to attain better and more profitable returns.

Many mining companies have of late years substituted crushing mills, such as are sometimes employed in the preparation of copper ores, for the stamping mill, and with great effect and benefit; inasmuch as the crushing mill reduces the ore to a finer state of division, and separates more of the gangue from the hard granules of tin than the stamps, and thereby renders it more easily and freely separable by virtue of its gravity, than when this breaking up is defectively performed. A mistaken notion or prejudice seems to occupy the minds of several miners, with regard to the value of crushers in their line of operations, the more especially if the stuff in which the tin ore is disseminated be indurated slate and the like; for in such cases they seem to be impressed with the idea that the crushers could not work it so well as the stampers. The evidence of many very creditable and experienced persons is directly opposed to this view; and a rational examination of the principles of working with regard to each, would undoubtedly tend to the preference of the crushers. At all events, since the tin miner places so much dependence upon the gravity of the ore as a means by which he can cheaply and expeditiously purify it from grosser and injurious matters, the primary consideration with him ought to be the reduction of the ore to the finest possible state of division. The better this is executed the more completely and expeditiously will the *whole* or chief part of the tin separate in virtue of its density, in a properly ordered system of elutriation.

ASSAYING OF TIN ORES.—Although the laws of the Stannery Court do not permit that the product of the tin mines should be sold out of Cornwall before smelting, it happens that the mining proprietors are never the smelters, and so the ores are sold to a few smelters who have the trade in their hands. These buy as cheaply as they can, and according to the declared value of the ore as ascertained by assay. Hence, as in the case of copper, the ores of tin are always submitted to

this test to find their value, and it becomes a matter of some interest to the miner, as well as the smelter, to be able to control the determinations of recognized assayers, for their own satisfaction and often protection. The operation is very simple, since the dressed ores are generally operated upon, and consequently very little of any other ingredient remains in the substance, excepting the binoxide of tin, and the silicious or other ganguey matter, separable by fluxes. Still, as binoxide of tin forms permanent compounds with silicic acid at a high temperature, it is necessary to use some precautions as well in the amount of flux allotted to the assay, as in performing the reduction in a black lead crucible, or an earthen one well lined with charcoal, and at the highest temperature of the wind furnace. If sulphurous or other alterable bodies be present in the ore, these should be removed by roasting a quantity of the ore at a low red heat, and using a little ammoniacal carbonate towards the end of the operation, till nothing further is evolved. The ore should in all cases be reduced to the finest powder; and after the roasting, if the quantity of silica and stony matter be deemed in too great excess, the assay may be carefully washed in a mortar or porcelain dish, and a large quantity of the impure matters thus removed. The heavy deposit of tin ore may then be dried and assayed in the following manner. If the ore be highly dressed, two ounces of it are weighed and mixed intimately with one-third to half this weight of powdered charcoal or coke, and half an ounce of ground borax glass; the whole well ground together, and introduced into a black lead pot, or lined clay one, and this placed on the furnace, the heat of which should be maintained at its highest point for fifteen to twenty minutes. At the end of this period, and when the contents of the crucible are in tranquil fusion, the whole is briskly stirred with an iron rod, and then poured out rapidly into an ingot iron mould. When cold, the slag is detached from the button of tin by a few strokes of the hammer, and by the use of the brush; the button is then weighed. Any matters remaining attached to the walls of the crucible are scraped off and ground, then washed, and the particles of metal that may be thus separated, weighed, and the amount added to that of the principal button. Sometimes the flux is composed of equal parts of borax glass and carbonate of soda, and is found to answer very well; so also is the flux compounded of three parts carbonate of soda and one of lime. Of the former thirty to forty per cent. of the ore taken for assay is employed, and of the latter forty per cent. When ores of tin are very poor, so that they necessitate the use of large quantities of flux, very little tin can be reduced from them, on the scale of assay-making, notwithstanding a considerable amount of the metal can be obtained by the treatment of such ores on the large scale. In assaying such ores the better course would be to employ the liquid method of analysis, which will be referred to further on.

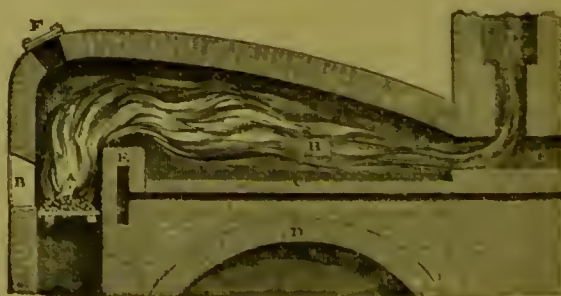
SMELTING THE ORE.—Up to the period of the reign of Charles the First, very little improvements are recorded in the smelting of tin. The remains of ancient workings discovered as existing previous to the above period, appear to indicate that the reduction

was carried on in furnaces or hearths scooped out of the ground, and in which a mixture of black tin and charcoal was placed, the necessary intensity of the heat being kept up doubtless by the blast of rude bellows, and the whole operation being similar to the metallurgic process of the travelling tinkers of a few years ago—and perhaps of the present day in Ireland—whereby cast-iron and other refractory metals were readily melted and cast into shapes, such as smoothing irons, *et cetera*. Remains of such furnaces are of frequent occurrence in Cornwall and Devon, and are called *Jew houses*. One of these smelting forges lately discovered beneath a stratum of bog, twelve feet thick, at Redmoor, contained some tin, peat which had been used as fuel, and furnace scoria, with other remains. An analysis of the scoria from other furnaces in the same locality, and apparently of a more modern date than the preceding, showed the imperfections of the methods of smelting. The following are the results which samples presenting the appearance of thin fragments of bottle glass gave:—

	Centesimally.
Silica,.....	40.60
Alumina,.....	19.20
Oxide of tin,.....	22.85
Protoxide of iron,.....	7.31
Sulphide of iron,.....	9.04
Lime,.....	trace
Potassa,.....	1.00
	100.00

From the other remains found in the site of the slags, *et cetera*, from which the above was taken, it would appear that the date of working could not have been later than about the year 1630. Attempts were made in the reign of the first CHARLES to employ pit coal instead of peat and charcoal; but the results were unsatisfactory till the first few years of ANNE's reign, when improved methods of smelting ores of tin in blast furnaces, by means of fossil fuel, were patented by a Mr. LIDDELL. At this period, and when the advantage of fossil fuel above peat and charcoal began to be recognized, the invention of the reverberatory

Fig. 604.

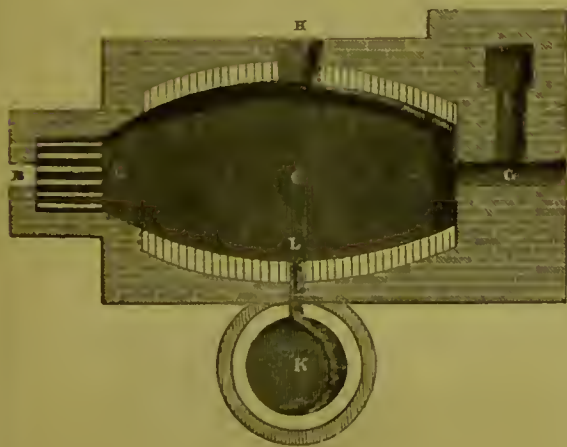


furnace soon followed, in which forms of furnaces tin ores have hitherto, but with slight modifications, been smelted. — *Records of Mining and Metallurgy*.

Figs. 604 and 605 are a plan and section of the smelting furnace at present employed in the smelting of tin ores. In these figures, A is the fire supplied through the door, B; C is the bed of the furnace, constructed of fire-

brick, and supported by the arch, D, having a passage for cold air beneath it, and in the bridge, E, of the furnace, to prevent the overheating of the mass of brickwork in the bed. The charging door is seen at H, and G is the opening through which the charge is worked in the furnace; F is a draught-hole temporarily opened whilst the slags are being skimmed off the metallic bath, and I is the flue leading to the chimney. The ore, which generally averages from sixty to seventy-five per cent. of metal, or, as estimated by the tin assayers and smelters, twelve to fifteen parts, in twenty of ore, is mixed with twelve to eighteen per cent. of powdered anthracite coal, and twenty to twenty-five hundredweight, or a little more, of this mixture, taken for the working charge in the ordinary sized furnace; a small quantity of lime or powdered fluor spar is added in proportion to the amount of silica contained in the material. The whole is shovelled in at the charging door, and spread through this and the working door; after which both doors are closed, and the fire is urged for a period of six to eight hours, gradually increasing in intensity. At the end of this time the ore is well rabbled and mixed by the furnaceman through the hinder door, with the view of bringing the unreduced portions of ore still remaining, within the influence of the heat, and reducing flame from the fire, and the unconsumed carbon of the charge, and likewise of allowing the separated metal to collect into a bath. For a second time the doors are closed, and the interior is allowed to regain its high degree of heat, somewhat reduced during the working of the mass. After a short interval

Fig. 605.



the furnaceman throws some moist slack on the surface of the fused mass in the furnace, and then commences to draw out the top layers of scoria through the working door, to the extent of three-fourths, or thereabouts, of the entire quantity. Whilst this part of the work is being proceeded with, it is customary to open the draught-hole, F, so as to allow the gases to ascend and leave the interior of the furnace partially exposed to the examination of the furnaceman. The above quantity of scoria, if skimmed off with care, contains no metal worth further search, and therefore it is thrown away. The portions which are afterwards drawn out, however, are separated into two classes; the first and largest portion is set aside to be stamped, in order to separate the

globules, or *prills* of metal diffused through it to the amount of five per cent., or nearly so; and the second, or final skimmings from the metal in the furnace, are reserved to be melted with a succeeding charge of metal or refuse products, when not only the particles of metal are recovered, but also the tin in the state of binoxide contained in it. When the metallic bath is cleaned in this way, the clay plug hitherto closing the gutter, L, leading to the east-iron pot, K, is removed, and the tin allowed to flow into the latter. The metal rests here for some time; meanwhile a fresh charge is introduced into the furnace; after which all the apertures are closed as before, and the fire kept up, as already stated. After the metal has remained in the pot sufficiently long to permit the slag and other impurities to rise to the surface, these matters are skimmed off, and the tin is ladled out into east-iron moulds, each capable of containing about three hundredweight.

The tin so procured always contains a certain amount of impurities, the greater when less care has been exercised in the dressing of the ore. These are generally iron, lead, and some other bodies, according to the nature of the accompanying ore, such as copper, tungsten, arsenic, and cobalt. To separate them, however, it is necessary to submit the crude tin to either of two operations—the one, a process by which the more fusible tin is sweated out at a low temperature, and called *liquation*; the other, a *boiling* or *tossing* of the metal, by which portions of it, by its extended exposure to the air in this operation, are converted into oxide; and being in this state agitated with the body of the metal, the oxygen is transferred to the more oxidizable metals, which are thrown off as a scoria, and can be removed by skimmings.

For the liquation, the smelting reverberatory above described, or one similarly constructed, may be used. The blocks of tin are loosely piled upon the hearth, and a moderate heat is applied; the excess of pure tin melts at the low heat, and flows out by the gutter to the receiver, leaving in the furnace an alloy richer in impurities, and therefore, owing to the more refractory nature of the alloyed metals, requiring a higher temperature for melting it than the purer tin. As the progress of heating crumbles and melts the blocks of tin, fresh ones are supplied till about five or six tons of metal have run out to the east-iron receiver, wherein the second operation is conducted. This receiver is so arranged as to admit of being heated with the view of aiding in the more ready separation of the contaminating ingredients during the boiling or tossing.

The purification by boiling is analogous in principle to the *poling* practised in refining copper, though differing in detail. In the case of copper, the gases eliminated from the wood—watery vapor principally, and some carbonylhydrogen—serve to decompose the metallic sulphide left, eliminating the sulphur as sulphurous acid and sulphide of hydrogen; whilst in that of the purification of tin, the metal abstracts oxygen from the steam similarly generated, and the oxide of tin thus partially produced, reacts upon the particles of alloyed metals more oxidizable than itself, and eliminates them as oxide, being itself reconverted to the metallic state.

The method of procedure with tin is to have a bundle of billets of green wood mounted on a crane erected by the furnace, and overhanging the pot containing the melted metal; this bundle is forced into the fluid mass, and the result is a violent seething, caused by the eliminated gases. A scum forms in which oxide of tin is a constituent; this is skimmed off and retained to be remelted with a fresh charge, or with the scoria produced in the first reduction. The action of the wood is renewed, and the scum removed, till by a test applied to the metal it is judged sufficiently purified.

Instead of using wood, the process of *tossing* may be practised with the same effect; that is, the metal is taken up in ladles and allowed to fall from a certain height into the caldron; in this case a scum is formed, and is removed in the same way as stated till the metal is deemed pure. The time occupied in the purification averages about five hours; one hour is devoted to the liquation, three to the boiling or tossing, and one to the subsidence of the metal after it has been thoroughly cleaned by the repeated skimming. During this final hour the metal disposes itself into three qualities of tin: the purer and more fluid metal constitutes the top layer, which is carefully cast or ladled into the moulds, and set aside as grain tin; the middle, which is not so pure, is likewise removed to moulds and retained as common tin; whilst the third portion is returned to the furnace to undergo liquation a second time, to purify it from the greater part of the vitiating ingredients.

The manner of testing the quality of the metal is as follows:—The refiner takes a small ladleful of the melted metal, and having cleaned it by stirring and skimming, casts it into a stone ingot mould, and as it cools, he closely observes its appearance. If it remains bright and clear, full and rounded on the sides, until quite cold, it is sufficiently pure to be classified as grain tin; if the metal, though bright, should not remain so full and rounded at the sides, and if at the moment of solidifying a frosted crystalline appearance shoots from the centre out to the sides, the tin is accounted as second class or common tin; and in the third place, if the metal assumes a slight yellowish appearance, and the crystalline stria appear much sooner, covering the whole of the surface, it is of the third class, and must be repurified by liquation, *et cetera*. The creaking sound emitted by the ingots when bent, is likewise a test which shows the quality of the metal, for this is much greater in proportion to the purity. In tin-smelting works, one day a week is usually devoted to the purification of the crude metal from the reduction of the ore.

The matter remaining in the furnace after the liquation of the tin, is melted at a higher temperature, and run out into another pot, whence it is cast into moulds. This, with the metal washed out from the rich slags after stamping, and the skimmings of scoria, as well as those produced in the refining pot, are resmelted, and the metal which results carried through the same course of operations detailed above. Finally, there remains in the pot a bright brittle alloy, having a crystalline fracture and so surcharged with foreign

metals that it is cast aside as not worth the expense and trouble of purification.

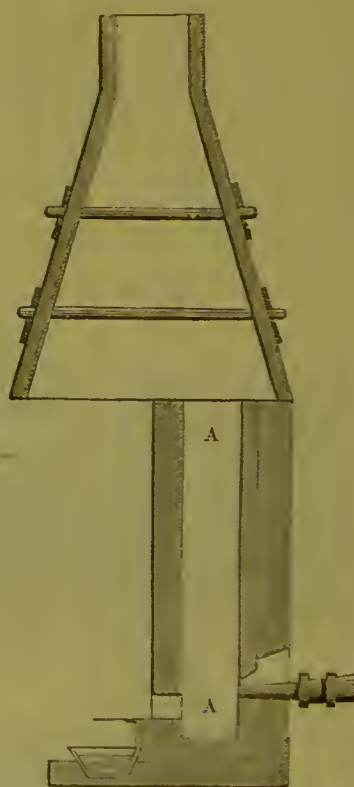
The following is the composition of the three qualities of tin obtained by the preceding operation, according to BERTHIER'S analysis:—

	Centimally.		
	Ordinary Tin.	Common.	Bad
Tin,.....	99.76	98.64	95.00
Copper,.....	.24	1.16	3.00
Lead,.....	—	.20	1.00
Iron,.....	trace	trace	—
Arsenic,.....	trace	trace	trace
Loss,.....	—	—	.50
	100.00	100.00	100.00

The consumption of fuel for producing one ton of tin is reckoned in the Cornish smelting works at a little more than a ton and a half, sometimes thirty-five hundredweight, and the loss of tin in the process amounts to about five per cent.

German Method.—In the tin-smelting establishment of Altenberg, *et cetera*, instead of the reverberatory, a

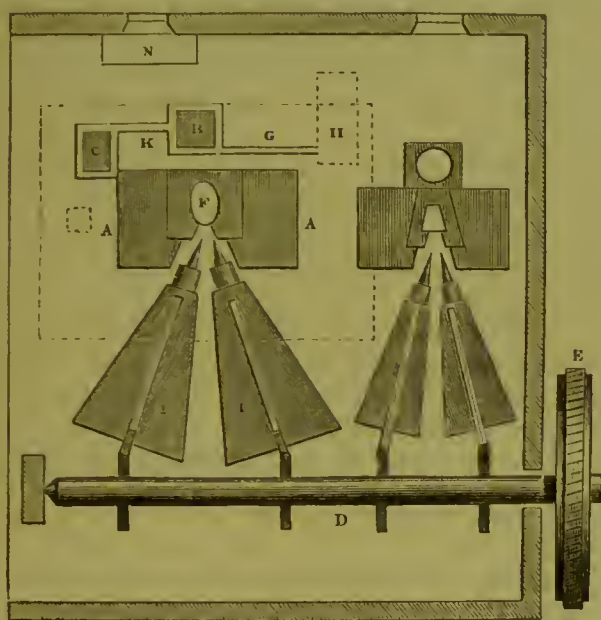
Fig. 606.



small blast furnace is used for the reduction of the ore. Figs. 606 and 607 are a plan and elevated section of this furnace; its height from the hearth to the throat, by which the mixture of ore and fuel is inserted, is fourteen feet. The body, A A, is constructed of large blocks of granite or of coarse-grained porphyritic syenite, and the sole or crucible is formed of a block of the same material hewn to the proper shape, with a fall to the breast of the furnace; but sometimes it is constructed of very refractory fire-bricks, lined with a mixture of charcoal and fire-clay well rammed down. A channel from the furnace leads into a basin, B, from which the slags flow down an incline, G, to the water

eistern, II, where they are cooled, and the tin by another conduit, K, flows into the vessel, C. The blast is supplied by the bellows, I I, through the tuyere opening, O. The furnace is surmounted by a dome which serves to carry off the vapors, and as a depositing

Fig. 607.



chamber for the particles of ore driven out of the furnace by the blast. The shaft, D, is turned by the cog-wheel, E, in connection with a shaft from a water-wheel or steam-engine. The small furnace, the parts of which are similar to the preceding, is employed for resmelting the slags produced from the larger furnace. The furnaces are slowly dried after their construction, and then charged with scoria and fuel, and the blast slowly set to work, so as to fuse the more vitrifiable portion, after which the heat is increased till the temperature is raised to the working intensity. The ore, mixed with the reducing agent, and other flux, when necessary, is now charged portionwise, and the smelting proceeded with. At the end of four hours the metal begins to flow. As the slags collect in the basin at the face of the furnace, they are skimmed into the water cistern, and when the metal accumulates so as to nearly fill the basin, it is allowed to flow into the outer one, C, whence it is cast into moulds of varied dimensions. Much of the same practical knowledge is required in the management of this furnace; as has been pointed out under the smelting of copper ores in the blast furnace; for the length of the nozzle formed of the slags, on the end of the tuyere affects the working, and the charge must be regulated accordingly.

It is affirmed that the tin reduced in the blast furnace is purer than that smelted in the reverberatory; but the loss of metal and the consumption of fuel is much greater; and these disadvantages have led to the abandonment of the blast furnace in England for the reduction of tin. Smelting by the use of the blast involves a loss of metal averaging fifteen per

cent., and a consumption of fuel amounting to three tons of coal for every ton of metal reduced.

Tin is sent to market as *block tin*, in blocks of three to half a hundredweight, and which are cast, as stated in the foregoing, in strips two feet long, one inch wide, and half an inch thick, being so cast in moulds of white marble; and in the form of *grain tin*; the last being produced by heating large blocks of the metal to nearly its melting point, and while in this state, dropping it upon a hard body from an eminence, or striking it with a heavy hammer—in either case, the mass is shattered into long crystalline fibrous columns.

USES OF TIN.—The principal uses of tin are for the manufacture of various alloys which are largely used in the arts, such as bronze, bell-metal, solder, *et cetera*; for making *tin plates*, or rather iron plates, alloyed with the metal; and for preparing tinfoil, whilst its compounds are employed for pottery, in glazes, and colors; and in cloth-printing, as mordants of great value and importance. The reader will find the account of bronze under COPPER, Vol. I., page 534, and of solder, usually compounded of two parts of lead and one of tin. Tin-foil is manufactured similarly to lead-foil, by passing slabs of it backwards and forwards under a pair of rollers; the temperature of the metal being raised occasionally, or maintained throughout, at 212°. The production of tin plates is one of the principal, if not the principal application of tin, and as such this manufacture will be described more in detail.

MANUFACTURE OF TIN PLATES OR SHEET-TIN.—

As the superior quality of tin plates depends almost entirely upon the goodness of the iron which constitutes their basis, and the care taken in its preparation, it will be necessary, from the importance of the subject, to dwell at some length upon this part of the process.

The pig-iron selected for the manufacture is generally that known as *red short*; but other varieties may be used, the iron being converted during the purification into plates, the essential qualities of which are great tenacity and toughness at ordinary temperatures. Iron from hematitic ores mixed with other pure ores of the coal measures, answers all the required ends. It has an average composition corresponding with the following samples, containing centesimally:—

	I.	II.	III.	IV.	V.	VI.	VII.
Carbon.....	3.47	3.70	2.37	3.42	4.23	3.27	—
Silicium....	1.40	1.33	0.81	1.63	0.49	1.03	1.55
Sulphur....	0.10	0.02	0.54	0.15	0.37	0.04	0.05
Phosphorus	0.60	0.12	0.26	trace.	0.36	0.38	0.18
Iron.....	94.43	94.93	96.02	94.80	94.55	95.28	—
	100.00	100.00	100.00	100.00	100.00	100.00	—

Tin plates are divided into two classes, and known by the terms *charcoal* and *coke* plates, owing, in the first place, to the nature of the fuel used in the preparation of the plates before tinning; but, more particularly at present, these names serve to distinguish the goods manufactured by entirely different methods. Charcoal tin plates were the first that were made, and they have been accounted the best. The iron for these plates is rendered tenacious and workable by the aid of a charcoal refinery through which the pig-iron, is passed; and that for the *coke* tin plates is prepared by the

ordinary method of puddling and rolling, as described under the article IRON. It will, therefore, be unnecessary to revert to the latter; and so far as the mere coating of the prepared plates is concerned, the description to be given will answer for both. To convert the iron into charcoal tin plates, it is necessary to refine it in a shallow furnace called a *refinery*, the sides and bottom of which are formed of hollow, but very massive blocks of iron, through which a stream of water is kept continually flowing, to protect them from the intense heat of the melted charge. This furnace is of a rectangular shape being four feet long, two and a half wide, and one and a half deep. On one side are three tuyeres for the admission of blast; and these are sometimes round, sometimes oval, the transverse diameters of each in the latter case being 1·15 inch, and its conjugate one inch; they are placed about a foot from the bottom of, and project considerably into the furnace, inclining downwards at a sharp angle. These, like the blocks forming the furnace, being subjected to a powerful heat, are protected by a coil of iron pipe, twisted round them, through which pipe a stream of cold water is kept always passing. Occasionally, refiners are constructed of larger dimensions than that described, having tuyeres at both sides; these are usually called *double refiners*. A coke fire is made in the space between the *water-blocks* or hearth, and the blast turned on till the whole is thoroughly ignited; a fresh supply of fuel sufficient to fill the space to the height of three feet above the tuyeres, is then heaped on; and, after a few minutes' blowing to increase the heat, a charge of pig iron, varying according to the size of the furnace, and generally reduced for the first time, is put on; the coke is soon ignited, and the metal attains a red heat quickly, after which, the heat being still kept up with fresh supplies of fuel, the metal gradually sinks, and as it comes into contact with the blast, it melts and drops to the bottom of the hearth. The downward direction of the tuyeres causes the stream of air to impinge on the highly-heated liquid iron, and thereby renders the temperature of the latter intense, owing to a portion of the metal being oxidized, as well as the silicium, sulphur, *et cetera*. All these products of oxidation are thrown up to the surface, and form a considerable amount of scoria or cinder that considerably aids in the depuration of the metal. Generally, in an hour and a half after charging, the furnace is fit for tapping; the metal is run out into iron moulds prepared for it, and which are protected against melting by a stream of cold water that flows beneath them. These moulds are sometimes flat, in which case the metal is called *plate metal*. In South Wales, however, it is more usual to run the liquid iron into moulds, consisting of three longitudinal grooves or channels,

having raised dams or *stops* at the distance of every five feet, to facilitate the breaking of the metal. As it runs out of the refinery, it is covered by minute, intensely brilliant, and very numerous cornications arising from the combustion of a portion of the fluid; these cornications are accompanied by a brown smoke—a phenomenon also of the BESSEMER process. As the metal runs out, the slag or cinder, which is likewise highly heated, flows after it, forming a layer on the surface of the moulds, and thus prevents further oxidation of the iron. Cold water is now thrown on the whole, when the cinder at once froths up and solidifies on the surface, causing it to assume a spongy appearance that distinguishes it from all other kinds of slag formed in the several processes for refining iron. The first charge worked in the refiner is less than the following one; but the normal weight, about twenty-two hundred-weight, is attained after the third. The number of charges worked every twenty-four hours is eleven or twelve; and the weight of refined metal produced in a week of six days and five nights averages sixty tons, for which about seventy-two tons of pig are required. The produce varies, however, according to the skill of the refiner, the quality of the material used, and the nature of the required product.

Good refined metal has a bright silvery-white fracture, and a radiated structure, the rays springing and diverging from the lower side; it emits a clear metallic sound when struck, is very brittle, with its upper surface indented into a kind of honey-combed structure, the depth of the indentations being dependent on the length of time that the iron has been subjected to the blast. About half an inch deep of honey-comb is considered to indicate the state of refinement best suited for the making of tin plates. It is somewhat curious that, as the refined metal graduates into steel, the honey-comb leaves the face or upper side, and tends to the centre of the horizontally-cast ingot.

The effect of the refining, as before stated, is the removal of the silicium, and of a portion of the sulphur and phosphorus contained in the crude material. The silicium is converted by oxidation into silicic acid, which combines with a portion of the iron oxidized, and forms a fusible slag or cinder on the surface of the metallic bath. The sulphur is converted into sulphurous acid gas, and passes off as such, and the phosphorus into phosphoric acid, which is retained in combination with the oxide of iron in the slag. Very little of the carbon, contrary though it be to the preconceived opinion of iron-masters, is removed during the preceding course of refining, as is sufficiently proved by analysis, and will be evident from an examination of the annexed table showing the composition of different specimens of refined iron:

	I.		II.		III.		IV.		V.
Carbon.....	3·070	....	3·250	....	2·000	....	3·200	....	—
Silicium.....	·630	....	·500	....	·540	....	·556	....	0·32
Sulphur.....	·157	....	·575	....	1·250	....	0·870	....	0·18
Phosphorus.....	·734	....	·835	....	·985	....	·920	....	·09
Manganese.....	trace	....	—	....	·056	....	trace	....	·24
Insoluble residue.....	·530	....	·050	....	—	....	—	....	—
Iron.....	95·140	....	96·300	....	94·255	....	95·000	....	—
	100·261		101·510		99·046		100·510		—

Although the above samples were not made from the cast-irons, the analyses of which have been previously given, yet they serve to prove what has been just stated regarding the chemical changes that take place in the fire. By comparing the results of the two series of analyses, it will be found that only one-seventh of the carbon is separated at the same time that one half of the silicium is removed. On the other hand the sulphur and phosphorus are in larger quantities in the samples of refined than in the crude metal, showing at least that very little if any of these elements are separated, or else that the crude material submitted to the process was of very bad quality. It appears, however, that fully one-third of the content of phosphorus and somewhat more than this amount of the sulphur, with nearly the entire silicium in the pig, are thrown off, the carbon suffering only a slight diminution.

The following analysis shows the nature of the refining cinder thrown off during the operation:—

Silica	23.76
Protoxide of iron	61.28
Oxide of manganese	3.58
Alumina	7.30
Lime	2.41
Magnesia	0.76
Sulphur	0.46
Loss	0.45
	100.00

Besides the foregoing method of refining, two others, long followed to some extent, are known—the first is a modification of BESSEMER's process, and the second is one patented by Mr. PARRY of the Ebbe Vale Iron Works. In the first, the action of the blast is stopped when the melted iron has passed to the state of refined metal; but as the iron prepared in this way has never been used in the manufacture of tin plates, it will be needless to prolong the description. The metal purified from common Welsh pig contains centesimally—

Sulphur	1.040
Phosphorus	1.128
Silicium	trace

PARRY's process differs considerably from those referred to. According to it the melted pig-iron is run at once from the blast into a reverberatory furnace very similar to that used in puddling. On each side of this are three or four small tuyeres pointing downwards to the hearth, through which superheated steam is forced at high pressure; they are so arranged that the current will cause a gyration of the surface of the metal, and thereby expose fresh surfaces of it continually to the blast. The action produced is similar to that effected in the ordinary refinery—the oxygen of the steam, together with that passing over the grate, causes the necessary oxidation, and, therefore, the formation of cinder as before. It should be observed that in this process a considerable quantity of rich cinder, such as hammer slags, mill-seales, *et cetera*, is added to the melted metal in the refinery, and the result of the union is that much of the iron in those cinders is reduced and converted into refined metal, so that in most cases the product equals the amount of metal introduced from the melting furnace. This

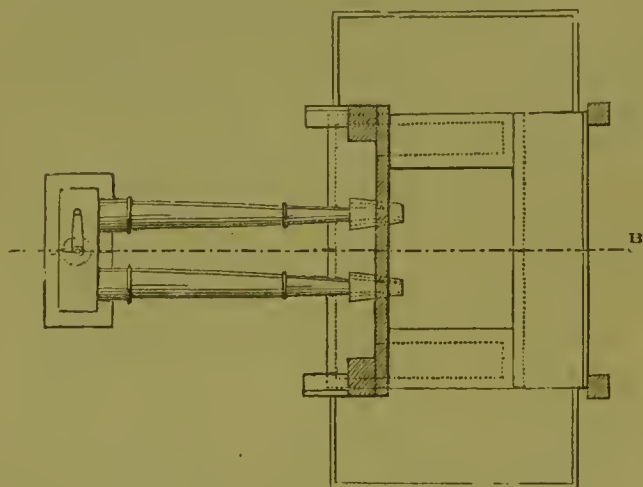
result is brought about by the carbon in the molten mass acting upon the rich slag, and reducing the iron in it to the metallic state simultaneously with its own consequent conversion into carbonic oxide, in which form it escapes; hence the cinder produced, though abundant, contains less iron than that formed under ordinary circumstances, namely, only thirty per cent. The hydrogen, likewise, has an important effect; it acts upon the sulphur and phosphorus of the metal, and converts these into sulphide and phosphide of hydrogen, which, like the carbonic oxide just mentioned, escape. The metal is thus rendered much purer, and well adapted for the manufacture of tin plates.

The next operation is the refining in the charecoal fire, in a furnace similar to the old blooming fire used in this country previous to the introduction of the puddling process. It consists of a shallow hearth eighteen inches deep, twenty-eight by thirty-two inches at the upper part, and twenty by twenty-one inches at the lower. On one side is placed a Δ -shaped tuyere protected, like the others spoken of, seven or eight inches from the bottom. The tuyere side and that opposite to it are occasionally constructed of *water blocks*, but generally of dry iron plates. Charecoal is the fuel used, and, in recently-constructed works, the products of combustion pass through a chamber at the back of the fire, and there raise the charge of metal to a red heat previous to its introduction into the fire. The refined metal being thus heated, it is drawn down into the fire, the whole of the hearth of which has been previously filled with charecoal, so as to completely cover the tuyere; more fuel is then added, and the blast turned on. In twelve to fifteen minutes the metal begins to melt, and at the end of forty-five minutes it is completely molten and lies on the bottom just under the blast. The workman now proceeds with a bar to break it up and raise it into more immediate contact with the blast, exposing it by this operation on all sides. A small quantity of cinder is thus formed, after which it is tapped off and another charge of heated metal let down and treated in the same way till the whole coheres into one mass. This occurs about an hour after charging. At this period it is usual in most tin works to add a bundle of shavings, cut from the edges of the *black plate* presently to be described. This new addition is very quickly blended with the previously formed *loops* of iron; so that in about ten minutes after adding it, the whole will be in one mass at the bottom of, and nearly filling, the hearth. During this part of the work very little fuel is required, merely sufficient to cover the iron. It is now taken out of the fire and freed from scurf and cinder as much as possible, all the pieces thus separated and the scales from the *helve* being taken back to the fire for the next charge. The loop is first hammered into a roughly cylindrical bloom and then into a flat irregular shape of about two inches thick. In this plate are cut deep grooves parallel with one another, and six inches apart. It is then thrown into cold water to cool, and broken into the rectangular pieces previously roughly indicated by the parallel grooves or notches. The charge of refined metal taken in this operation is about two hundred and seventy pounds, and the loss is such that to make one ton of

charcoal-refined, or stamped iron, as it is sometimes called, requires twenty-two hundreds of refined metal and about eight bags—equal to one hundred and twenty cubic feet—of charcoal. The number of charges worked off in the twenty-four hours averages eighteen.

The effect of this process is to continue, and, in a

Fig. 608.

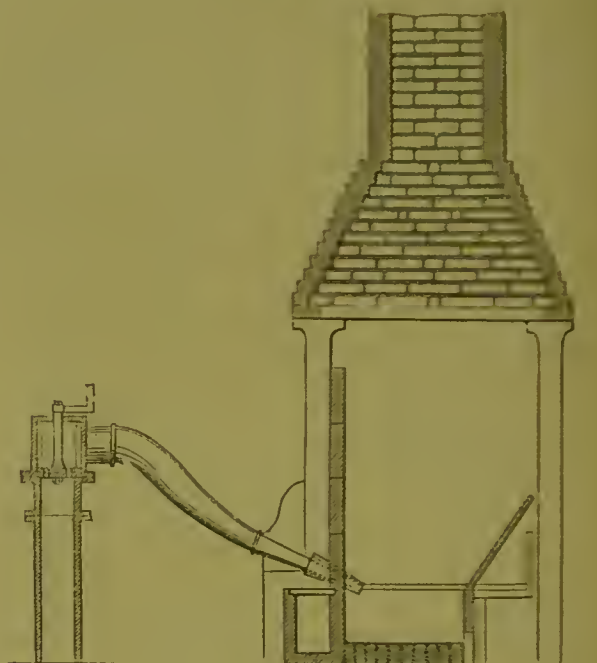


in which it breaks under the hammer. In fact this is almost the most important operation in the whole series which constitute in the aggregate the manufacture of tin plates; and if it be not properly conducted all subsequent treatment results in loss and vexation. The chemical reactions that are effected are a continuation of the carbon in the iron, and the separation of the sulphur and phosphorus, with other impurities, by the same agency. The similarity between the two methods now treated of and the BESSEMER process must be apparent to every one; the only difference being the presence of carbon in both, the plans described, to prevent the excessive oxidation and loss resulting from the patented method of BESSEMER.

In some works it is usual to run the fluid metal direct to the charcoal fire, and this practice certainly economizes fuel, as all the caloric absorbed in raising the refined metal from its cold state to the melting point must be saved. When this is the case, the refinery is made very much smaller than that before mentioned, and is charged with only six hundredweight of pig, which, when refined, supplies two charcoal fires. This kind of furnace is often called a *running out* or *dandy fire*—Figs. 608 and 609, the former a plan and the latter a vertical section on the line A B of the plan—and is now very generally used. Instead of using charcoal in these fires, it is customary in some localities to use a very light, spongy coke, and this difference gave rise to the terms *coke* and *charcoal* plates, though at present the former name is applied to puddled iron. Coke of this nature has received great attention recently; and there can scarcely be a

great measure to complete, the purification begun in the previously described process, the result being, in fact, crude wrought-iron. The fresh fracture presents very large, bright, and flattish crystals, of a silvery color; and its fitness for the subsequent process is mainly judged of by its appearance, and by the manner

Fig. 609.



doubt of the fact that if this fuel is carefully manufactured from a proper and pure coal, and finished by the action of steam while hot, according to a process lately patented by Mr. R. S. ROPER, it forms as good a fuel as charcoal; and that tin plates made in this way are not to be distinguished in appearance or quality from the charcoal plates.

The charcoal iron next undergoes a reheating and welding process. One of the rough irregularly oblong pieces, weighing about thirty pounds, is laid on a flat plate of iron with a long handle, called the *portal* or *staff*, and placed in the *hollow fire*—shown in elevation in Figs. 610 and 611—where it is raised to a soft welding heat previous to reducing it to blooms. Fine sand is thrown on the surface of the metal from time to time, to remove the oxide or *scale* formed on it by the action of the heat and the free oxygen entering the fire, which scale, if left on it, would interfere with the proper welding. Afterwards it is carried to the hammer and beaten into a bloom, as stated above, and welded to the portal; this is again returned to the hollow fire, three other pieces of the charcoal iron being previously placed upon it, and after its temperature is raised as before, again worked into a bloom six inches wide and two thick under the hammer. This is cut nearly in the middle, and the parts doubled up on one another—reheated—rehammered into a bloom six inches by four—then taken to the hollow fire to be reheated—cut off from the portal—and finally passed several times through a series of grooves in a pair of rollers till it is reduced to a bar or slab six inches wide and half an inch thick. These dimensions,

however, vary slightly particularly the thickness, according to the size and gauge of the plates afterwards to be rolled from them.

The *hollow fire* alluded to is one of the earliest applications of the gas flame to metallurgical purposes, having been in use upwards of seventy years, previous to which an earlier form, was used, and is still employed in the charcoal forges of North Lancashire; in this early form the iron was surrounded by a dome

Fig. 610.

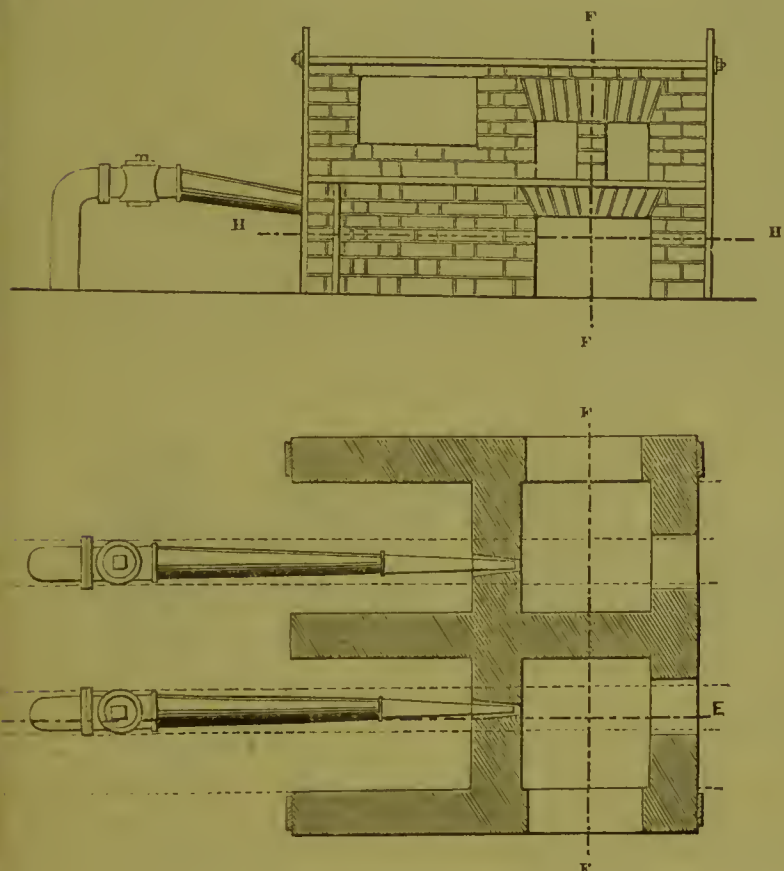
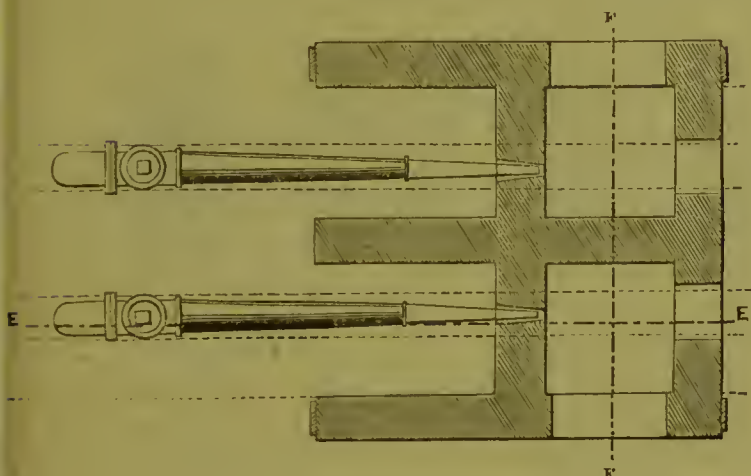


Fig. 611.



of ignited fuel, the flame from the combustion of which produced the necessary heat. In the present modification, the furnace is of bricks, and in three divisions—at one end is a space containing ignited coke, into which a continued blast of air is blown by two tuyeres; the flame thus produced passes into the middle position, where the iron to be heated is placed; and the third or middle-end division is intended for the partial heating of said iron by the waste heat, preparatory to its being introduced to the middle division.

The operation just described is a most wasteful one, involving a loss of three or four hundredweight of iron per ton of bars made; and this is the more striking as the material operated on is wrought-iron. It is owing chiefly to the numerous heatings to which the metal is submitted, and the large volumes of oxygen that enter the furnace through its numerous openings, and possibly also the excess of blast blown into the coke. The latter cause of loss might be avoided by care on the part of the workmen; but it is to be feared that the waste can be but slightly diminished while so many

apertures for the entrance of air are allowed to exist. To remedy the evil many experiments have been made to avoid this process altogether, but hitherto without leading to the adoption of any advantageous plan. Mr. WILLIAM DANIEL patented a mode of dispensing with the operation, but it is only partially carried out, though it was in a great measure successful. He directs to put the lump from the charcoal refinery under the hammer, where it is *nobbled* or hammered into a roughly cylindrical bloom, then passed through the rolls and reduced to a bar six inches square and about two feet and a half long. This bar is then either cut or sawn into pieces six inches long, and rolled endwise to give a bar six inches wide, two and a half thick, and twelve long; afterwards this billet is heated in a small balling furnace, and rolled down to a bar a quarter of an inch thick, eleven wide, and about six feet long. This is at once taken to the tin plate mill and made into plates.

It is necessary to revert here to the *coke tin plates*, which name, as already stated, was originally applied to them in consequence of the kind of fuel used in the second refining operation. At present it means those produced from puddled iron rolled into bars similar to those described in the preceding, and called *tin-plate bars* or *tin bars*. In all the subsequent processes the same *modus operandi* is followed, whether the tin bars be made from the puddled or from the hollow fire iron—charcoal tin bars; therefore the following description of the process to which the bars are subjected, previous to, and up to their conversion into tin plates, applies equally to both kinds.

The bars are taken to the shears, where they are cut to proper lengths in accordance with the size of plates to be made—thus for No. 1 c plate, which is $13\frac{1}{4} \times 18$

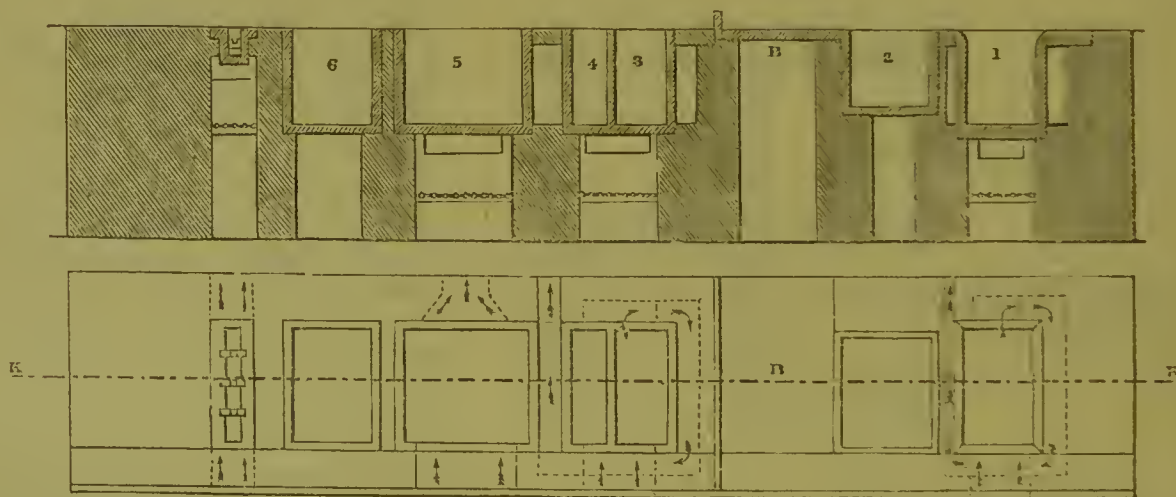
—see table, page 1071, the length of piece will be fifteen inches, the exact dimensions of it being $15 \times 6 \times \frac{3}{8}$ inches. These short pieces are then placed in packs in a reheating furnace, having a very slow draught, and there raised to a dull red heat; they are next passed singly breadthwise several times through a pair of narrow flat rolls; reheated, and then drawn out across the original fibre to a length of five feet and a half. Such plates are then doubled down, and the ragged ends produced in the rolling shaved off. After this they are returned to the furnace and heated to redness, passed through a pair of rollers similar to the last, but more carefully turned to give them a very smooth surface, and there rolled till each is drawn out to five feet—this virtually being two plates five feet long united at one end. The combined plates are again doubled, the waste end sheared off, returned to the fire, and when heated repressed under the rolls till they are extended to about forty-three inches, the entire forming four plates. The operation of doubling, heating, and rolling, is continued sometimes till the original plate is reduced to eight and even sixteen

plates, all passing under the rollers as one. It is to be observed, that great care is required to prevent the plates from being welded either by a too high heat, or from a neglect of partially separating them from time to time, by the rollers. In this way the original piece of bar is rolled into four sheets, each forty-three inches long by fifteen wide. The plate of four, eight, sixteen, or thirty-two thicknesses, or sheets, is then taken, unopened, to a pair of shears, which cut off the two ragged longitudinal edges at one stroke, and at such distances as to determine the length of the tin plates; they are then cut across by the same machine at distances equal to the intended breadth of the same; and thus are obtained four, eight, sixteen, or thirty-two plates in each division of the proper dimensions, still so closely pressed as apparently to be but one. They are next separated, and all the defective ones picked out; such, for instance, as contain streaks of dirt pressed into them, those welded together, and the like, and the choice ones, called in this state *black* plates, are taken to the *pickling* room. Here they are immersed in a bath of warm dilute oil of vitriol during fifteen or twenty minutes, to remove the scale of oxide

on them. The acid leaves them with a clean dull grey metallic surface; and to assist the action of the acid in this respect the plates are rubbed with sand and water, and afterwards washed, when they are ready to be sent to the *annealing* house.

It will be readily understood that, after the repeated rollings and the immense strain the plates have been subjected to, they are at this stage very brittle; and therefore, if turned in this state, they would not bear to be hammered into the multitudinous and complex shapes required in commerce. To remove this defect, the process of annealing is had recourse to, and the work is conducted thus:—The plates are placed to the number of about eighteen hundred—for common sizes—in piles, within a cast-iron box about two feet square, the lid carefully luted on to prevent air entering and then placed with several similarly filled ones in a stove constructed very much in the shape of a reverberatory furnace, but considerably larger, and having its bed on a level with the ground. The fire-bridge being tolerably high, the flame from the grate rolls slowly over the boxes, and raises them gradually to a cherry-red heat, at which temperature they are main-

Fig. 612.



tained during twelve hours, and then withdrawn. When quite cold, the covers are taken off, the plates taken out, carefully examined, and sorted. If the heat has been too high, some of the plates will be found adhering to one another; if too mild, they will not be much improved by the operation, and if air should have entered, they will be either partially or completely converted into scale or oxide of iron. After being subjected to this process, the plates will have a deep plum-color bloom on their surfaces, due to a very thin film or coating of oxide that has formed upon them. They are now passed three times through a pair of rolls similar in form to those previously described, but with which great pains have been taken, to make their surface hard, smooth, and brilliantly polished. Then rolls are placed in close proximity, so that the plates passing between them are subjected to a very great pressure, but not sufficient to enlarge them. After having been thus *cold rolled*, as it is termed, the plates are extremely smooth, and possessed of a lustrous and dappled appearance, still owing to

the thin oxidation. One effect of this rolling is to make the plates brittle once more, and therefore to necessitate a second annealing, which is performed in the same way as the preceding; but the heat is milder, and the time reduced to five or six hours. Another sorting follows, when the good plates are sent to the *tin house*, and the defective ones returned with the shearings of the *black* plates to the *charcoal* fire.

In the tin house the plates are again *pickled* in a warm but more dilute bath of oil of vitriol than that already used, during ten minutes, then removed and well rubbed with sand and water, to detach all dirt and scale. They should now have a smooth, perfectly clean, greyish metallic surface, in which state they can be kept in cold water without injury for some time, and are ready for the *tinning*.

TINNING.—The apparatus or *stove*—Fig. 612—for this process consists of a series of baths set side by side, for the convenience of the workmen, each bath having a fire beneath it, to keep the materials they severally contain in a fluid state. These baths

or pots are six in number—namely, 1, the tinman's pot; 2, the tin-pot; 3, the washing or dipping pot; 4, the grease-pot; 5, the cold-pot; and 6, the list-pot. The tinman's pot is full of melted grease, and into this the plates are immersed and left till all moisture upon them is evaporated, and they become completely covered with the grease. It is about two feet long, fifteen inches wide, and twenty inches deep. From the tinman's pot the plates are removed to the tin-pot, and plunged into the bath of melted tin, protected with a layer of grease which it contains, and remain in it for about twenty minutes. This pot has a capacity of $22 \times 18 \times 16$ inches. In the first dipping the alloy is imperfect, and the surface not uniformly coated, consequently the plates are removed to the dipping or wash pot, which is divided into two compartments. The first immersion takes place in the larger division, which contains molten tin covered with grease like the last, and here the plate is left sufficiently long to make the alloy complete, and to separate any superfluous tin which might have adhered to the surface. The workman then takes out each plate separately to a table between the wash-pot and the grease-pot, and wipes it on each side with a brush of hemp to remove any excess of tin; to obliterate the marks of the brush, he dips it quickly into the second compartment of the wash-pot, and then at once into the grease-pot. This second compartment of the wash-pot always contains the purest tin; and as it becomes alloyed with iron, it is removed to the first compartment of the same, and thence to the tin-pot. The grease-pot is filled with melted grease; and great care is necessary to maintain it at the proper temperature. Its purposes are to allow any superfluous tin to run off, and especially to prevent the alloy on the surface of the plate cooling more rapidly than the iron. If this were neglected, its surface would be cracked. After ten minutes' immersion in the grease-pot the plate is removed to the cold-pot, which is filled with tallow heated to a comparatively low temperature. The pots 4 and 5 serve the purpose of annealing the plates, and of cooling them down

to a low temperature. The last one in the series is the list-pot, and is a small cast-iron bath kept at a sufficiently high temperature, its bottom covered with tin to the depth of a quarter of an inch. In this the edges of the plates are dipped and left in till the wire of tin, which usually forms on them in the course of the foregoing processes, melts, and is removed by a quick blow on the plate with a stick.

The articles are now tin plates; but before they are sent to market, they undergo some further treatment. Firstly, they are carefully rubbed with bran to clean them from grease and dirt; secondly, they receive another rubbing with a pad of sheep-skin, retaining its wool; and thirdly, they are sent to the sorter, whose duty it is to pick out defective plates, and to arrange the good ones in piles according to their size and quality. They are finally packed in boxes, which are branded on the outside with the marks indicating the size and quality of the plates, and sent to market.

Quality of Tin Plates.—The tests for tin plates are ductility, strength, and color; and to possess these, the iron used must be of the best quality, and all the process be conducted with care and skill. The following conditions are inserted in some specifications, and will serve to indicate the strength and ductility of first-class tin plates:—

1st, They must bear cutting into strips of a width equal to ten times the thickness of the plate, both with and across the fibre, without splitting; the strips must bear, while hot, being bent upon a mould to a sweep equal to four times the width of the strip.

2nd, While cold, the plates must bear bending in a heading machine, in such a manner as to form a cylinder, the diameter of which shall at most be equal to sixty times the thickness of the plate. In these tests, the plate must show neither flaw nor crack of any kind.

The following table exhibits the usual brands and their value in dimensions of plate, number, and weight per box, and may be found useful for reference:—

TABLE OF MARKS, WEIGHTS, AND DIMENSIONS OF TIN PLATES.

Name.	Size. Inches. Inches.	Number in box.	Weight of box.			Mark or brand.
			cwt.	qr.	lbs.	
Common, No. 1,	$13\frac{3}{4} \times 10$	225	1	0	0	IC
“ No. 2,	$13\frac{3}{4} \times 9\frac{1}{2}$	“	0	3	21	HC
“ No. 3,	$12\frac{3}{4} \times 9\frac{1}{2}$	“	0	3	16	HC
No. 1, cross,	$13\frac{3}{4} \times 10$	“	1	1	0	IX
No. 1, 2 “	“	“	1	1	21	IXX
No. 1, 3 “	“	“	1	2	14	IXXX
No. 1, 4 “	“	“	1	3	7	IXXXX
Common doubles,	$16\frac{3}{4} \times 12\frac{1}{2}$	100	0	3	21	CD
Cross doubles,	“	“	1	0	14	XD
2 cross doubles,	“	“	1	1	7	XXD
3 “	“	“	1	2	0	XXXD
4 “	“	“	1	2	21	XXXXD
Common small doubles,	15×11	200	1	2	0	CSD
Cross “	“	“	1	2	21	XSD
2 cross “	“	“	1	3	14	XXSD
3 “	“	“	2	0	7	XXXSD
4 “	“	“	2	1	0	XXXXSD
Wasters, common No. 1,	$13\frac{3}{4} \times 10$	225	1	0	0	ICW
“ cross No. 1,	“	“	1	1	0	IXW
“ common small doubles,	15×11	200	1	2	0	CSDW
“ common doubles,	$16\frac{3}{4} \times 12\frac{1}{2}$	100	0	3	21	CHW
“ cross doubles,	“	“	1	0	14	XIHW

The Editor thankfully acknowledges his obligations to his late talented pupil, Mr. R. S. ROPER, for his assistance in preparing the preceding remarks on tin plates.

ULTRAMARINE.—*Outremer*, French; *Lazurstein*, German.—This is one of the most beautiful pigments known, and its artificial production is justly viewed as belonging to the greatest triumphs of modern chemistry. It is obtained by isolating the coloring matter of lapis-lazuli, outremer, or lazurstein, mostly brought from China, Thibet, and the shores of Lake Baikal. It is a mineral of indeterminate composition, as will be seen from the annexed analyses—

	Gmelin.	Dann.
Silicic acid,	49.00	45.50
Sulphuric acid,	2.00	5.90
Alumina,	11.00	31.80
Soda,	8.00	9.10
Lime,	16.00	3.50
Magnesia,	2.00	—
Sesquioxide of iron,	4.00	0.80
Sulphur,	trace	—
Water,	trace	—
Chlorine,	—	0.40
Loss,	8.00	2.00
	100.00	100.00

Lazulite often contains scales of mica and iron pyrites. It is found in masses, more or less pure, generally in small volume, fragile, but capable of scratching glass, of granular texture, imperfectly laminated, and almost transparent at its edges. It crystallizes in dodecahedrons, with rhombic faces, but the crystals are rare—specific gravity, 2.50 to 2.96. The hue, which occurs in isolated places, merges from celestial to pure blue and indigo purple. It is usually disseminated in a rock, which contains many other laminated substances, among which is a fine white lazulite. In the *Musée Mineralogique* at Paris are two fine specimens of lazulite, in which is seen the transition from the azure to the white. TOMLINSON remarks that the iron pyrites sometimes propagated in lazulite, is of a bright yellow hue, helping to relieve the lustre of the blue, and they have often been mistaken for pellets of gold; in fact, the cause of its intense blue color was long a matter of controversy. No traces could be detected of cobalt, copper, or any other element or compound known to impart an azure tint. The existence of an unknown protoxide of aluminium— AlO —was even assumed as a means of solving the difficulty; and not until ultramarine had been prepared artificially, and the synthetic proof had thus been superadded to the analytical, was it admitted that a blue tint could be produced by the union of three colorless bodies—*alumina*, *sulphur*, and *soda*.

CLÉMENT and DÉSORMES published an analysis of this substance in 1806; they admit, of course, the great difficulty experienced in analyzing ultramarine. They regarded it to have the following composition, which is in many respects similar to the results obtained by WILKENS, and subsequently given—

	Centesimally.
Silica,	35.80
Alumina,	34.80
Soda,	43.20
Sulphur,	3.10
Carbonate of lime,	3.10
	100.00

The great cost of ultramarine, and the unparalleled effects which it produces in painting, rendered it most

desirable to produce this compound artificially. Chemists were for some time baffled by the discordant results each obtained, and were thereby unable to distinguish which of the ingredients of ultramarine were essential, and which accidental or superfluous.

The first step, says TOMLINSON, towards the production of this pigment artificially was in 1814. VAUQUELIN, in visiting the plate-glass works at St. Gobain, was informed by the director of the sulphuric acid and soda department of the establishment, that, in taking down the soda furnaces a blue mass was found where *grés*—gritstone—was employed in the formation of the sole, but there was no such deposit when the sole was of brick. The Editor has often remarked in black-ash furnaces the production of ultramarine; in fact, all recent analyses of this substance give about one per cent. of this blue pigment. VAUQUELIN took some of the compound, reduced it to powder, and, washing it, found it was decolorized by the mineral acids, with the disengagement of sulphide of hydrogen; that it was not attacked by boiling alkaline solutions, nor destroyed at a red heat. This chemist further states, that though the composition of this artificial product is unlike that of lapis-lazuli, yet he is not without a hope that the circumstance may lead to the production of ultramarine artificially. This observation, and the suggestion founded upon it, appears to have been forgotten for nearly fourteen years. To GMEIN of Tübingen the honor of the discovery of artificial ultramarine is generally said to be due; but, as TOMLINSON remarks, if the question of priority were raised, then it must be claimed by the *Société d'Encouragement* of Paris, who offered a prize of six thousand francs for the manufacture of ultramarine. GUIMET obtained the prize in 1828, on which occasion he communicated his recipe confidentially to GAY-LUSSAC.

To prepare the pigment lapis-lazuli, freed from all mechanical impurities, is gently ignited, slaked in water, and reduced to an extremely fine powder. This is now incorporated with a melted paste called *pastelle*, consisting of linseed oil, wax, and resin, and kneaded under cold water. Ultramarine gradually deposits in the vessel as a dark-blue powder, which grows brighter by degrees, whilst the impurities remain entangled in the *pastelle*.

The color thus obtained is of necessity very expensive, from the rarity of the material, and from the tedious and wasteful mode of producing it.

The preparation of artificial ultramarine has undergone many modifications since the experiments of GMEIN. BRUNNER mixes seventy parts of silica, two hundred and forty of burnt alum, forty-eight of charcoal powder, one hundred and forty-four of flowers of sulphur, and two hundred and forty of anhydrous carbonate of soda, all reduced to an impalpable powder: puts the mixture in a Hessian crucible, and lutes down the cover. The crucible is heated to moderate redness, and kept steadily at that temperature for an hour and a half, and then suffered to cool. If the operation has succeeded, the mass has a loose, half-fused appearance, and a greenish or reddish-yellow hue. If solid, fused, and brownish, the heat has been too high. The mass is taken out of the crucible, and washed till the liquid has no longer a sulphurous taste. The residue, a dark

greenish-blue powder, is filtered, dried, mixed with its own weight of sulphur, and one and a half times its weight of anhydrous carbonate of soda, and heated as before. The residue is boiled with water for some time, filtered, and washed till the liquid no longer blackens carbonate of lead. The dried powder is sifted, and submitted to the following final process:—A plate of cast-iron is covered to about the depth of a line with pure sulphur, upon which the compound is sifted to about an equal depth. The plate is then cautiously heated till the sulphur takes fire. The residue is removed from the plate, again pulverized, and resubmitted to the same treatment with sulphur, until the color is found satisfactory.

PRUCKNER adopts a somewhat modified process. Sulphide of sodium is prepared by igniting sulphate of soda with charcoal powder. This is dissolved in water, some free sulphur is added, the liquid is concentrated, mixed with one half per cent. of sulphate of iron and twenty-five per cent. of a well-tempered clay—the purer and whiter the better—the mixture evaporated to dryness, the residue powdered, and ignited for an hour in a cupelling furnace; when cold, it is extracted with water, the residue dried, powdered, and once more heated in a muffle, when the required tint appears.

A still further simplification is to ignite sulphate of soda with charcoal powder and clay in a crucible, with slight access of air.

TIREMON'S recipe for this pigment is the following:—One thousand and seventy-five parts of crystallized carbonate of soda are fused in their own water of crystallization, and the fused mass mixed by stirring, first with five parts of red sulphide of arsenic, then with a quantity of hydrate of alumina, prepared from alum by precipitation with carbonate of soda, and containing seven parts of anhydrous alumina, and lastly, with a mixture of one hundred parts of sifted clay, and two hundred and twenty-one parts of flowers of sulphur. The mass, after being intimately mixed and evaporated to dryness, is introduced into a crucible provided with a good cover, and gently heated at first, in order to expel the remaining traces of moisture, the temperature being afterwards raised to full redness. The mass should cake together without fusing. If the materials have not been properly mixed, the whole will exhibit white spots; and if it has been fused, it is studded with brown ones. After cooling it is roasted, in order to expel the greater portion of the sulphur, then reduced to powder, and washed slightly on a filter with cold water. The bluish-green powder thus obtained is again roasted for an hour or two, with occasional stirring, in covered basins, at a temperature never exceeding low redness. According to ELSNER, a very small quantity of iron, such as is usually contained in the ingredients, is *essential to the production of the hue*, but excess is injurious. A mixture of one part of clay, perfectly free from iron, with one part of sulphur and two parts of anhydrous carbonate of soda, yields a yellowish mass when ignited; but if a trace of sulphate of iron is added to the mixture, a mass is obtained which is black, green, or blue, according to the degree of heat to which it has been subjected. When potassa is used instead of soda, GMEIN states the blue tint is not obtained.

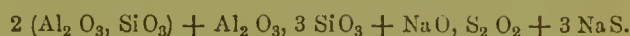
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Before the analysis by MARGRAF, the color of ultramarine had been attributed to the presence of copper, but this chemist only found sulphuric acid, lime, and iron; others suspected, naturally enough, the presence of cobalt; others again, hydrofluoric acid. KLAPROTH'S results indicated the following:—

Carbonate of lime,	28.00
Sulphate of lime,	6.50
Alumina,	14.50
Silica,	46.00
Sesquioxide of iron,	3.00
Water,	2.00
	100.00

GUYTON thought that the coloring matter was a blue sulphide of iron.

Pure ultramarine, according to WILKENS, has the composition—



It should contain, therefore, theoretically—

	Per cent.
Silica,	38.75
Alumina,	26.37
Sulphur,	13.68
Soda,	21.20
	100.00

an assumption which agrees pretty closely with the actual analysis of the purest samples. A variety of substances, such as iron, lime, potassa, magnesia, sulphuric acid, and chlorine, may be present as impurities, and were, in part at least, purposely added by the earlier manufacturers; but they are found to be perfectly unnecessary. The coloring matter appears to consist of hyposulphite of soda and sulphide of sodium. If the firing be conducted in porous crucibles, the coloration of the mass is generally unequal.

GREEN ULTRAMARINE.—Ordinary ultramarine, on ignition with saltpetre, assumes a green color. Green portions, more or less in quantity, are frequently formed in the crucibles, especially on the first ignition. On repeated heating it passes into a blue tint. Artificial ultramarine is, however, very rarely entirely freed from all traces of the green modification, and hence it is, for the most part, less beautiful than the natural variety.

Ultramarine is readily decomposed by acids, with evolution of sulphide of hydrogen, and total destruction of the color. At a high temperature this effect is even produced by silica, whence the unfitness of ultramarine for painting on glass and porcelain. Solutions of potassa and soda have no decomposing action, even at a boiling temperature. By a prolonged red heat ultramarine is rendered perfectly white, and then no longer evolves sulphide of hydrogen on the addition of an acid.

Tests.—Purchasers frequently judge of the comparative value of samples of ultramarine by mere inspection—a most fallacious method. The eye may indeed decide on the purity of the blue, but it can give very little notion of its depth. In other words, it is impossible to determine, by mere inspection, how far a sample has been let down with some colorless substance. It is better to take equal weights of the respective samples under examination, and to grind up each with

ten to twenty times its weight of gypsum. When thus let down, a difference in the depth of color becomes perceptible.

BERNHEIM prepares a normal solution by mixing one ounce of concentrated sulphuric acid with twenty grains of water; equal weights—fifty to one hundred grains—if the various samples to be examined are next taken, and each placed in a separate glass. The normal liquor is now added from a graduated burette until the blue color is converted into a reddish one, and no blue particles are perceptible. The quantity of sulphuric acid consumed in each case shows the relative value of the sample. If cobalt is present, the blue color of the sample cannot be completely destroyed by the acid.

Uses.—Ultramarine is employed as a pigment by artists and decorators. Under certain circumstances, however, it gradually loses its color if ground with oil. It is also used in printing cotton and woollen goods, being fixed to the fibre either by solutions of albumen and casein, or by shell-lac varnishes. It is abundantly employed as a *powder-blue*, in getting up white cotton and linen goods. For this purpose it is ground up with soda-ash, chalk, gypsum, or any other cheap white matter, and sold sometimes under its own name, but more frequently as superfine Saxon smalts. This fraud is much in vogue in a sea-port town on the Eastern coast of England notorious for its manufacture of inferior and spurious colors. The detection is not difficult, since hydrochloric acid at once destroys the color of ultramarine, whilst it is without action upon genuine smalts.

VARNISH.—*Vernis*, French; *Firniss*, German.—In the commonest acceptation of the term, a varnish consists of a resin of some description dissolved in a fluid more or less volatile, which, on evaporation, leaves the resin in the form of a lustrous film. It is generally applied by means of a brush in successive coats, and is laid on in the direction of the fibres of the wood. The most desirable feature of a good varnish is durability, dependent upon the quality of the resin and its solvent.

The principal substances employed in making varnishes are the following:—

SOLVENTS.

Oil of nuts—alcohol.
Oil of linseed—ether.
Oil of turpentine—wood-spirit, pyroxilic alcohol, or hydrated oxide of methyle.
Oil of rosemary—methylated spirit.

SOLIDS.

Amber,	Colophony,	Elemi,
Anime,	Copal,	Lac,
Benzoin,	Damara,	Mastic,
	Sandarac.	

COLORS.

Aloes,	Dragon's blood,	Red saunders,
Annotto,	Gamboge,	Saffron,
Cochineal,	Indigo,	Turmeric.

The spirituous varnishes dry most rapidly; this advantage is, however, partly counterbalanced by their aptitude to crack and to peel off. This defect is partially remedied in the turpentine varnishes which dry more slowly. But in those called *oil-varnishes*, this defect is alone entirely obviated: in these a small quan-

tity of a drying oil is added to the solution of the resin in rectified spirit of turpentine; and although they take a longer time to dry, they are all the more durable.

Before treating of the various varnishes, a description will be given of the chief resins before mentioned, as being employed in the manufacture:—

Amber is most distinguished for durability. It is usually of some shade of yellow, transparent, hard, and moderately tough. Heated in air it fuses at about 549°; it burns with a clear flame, emitting a pleasant odor. When pounded, absolute alcohol extracts succinic acid and resin; the latter to the extent of about one-eighth of the weight of the amber. In fact, amber is a mixture of several resins. It resists the action of solvents so greatly, that it requires to be fused and kept in a state of fusion—for oxidation—at a somewhat high temperature before it is fitted for making amber-varnish. The costliness of amber, as well as the length of time it takes to dry, are the chief objections to it.

Anime is imported from the East Indies. The large, transparent, pale-yellow pieces, with vitreous fracture, are best suited for varnish. Inferior qualities are employed for manufacturing gold-size or japan-black. Although superior to amber in its capacity for drying, and equal in hardness, varnish made from anime deepens in color on exposure to air, and is very liable to crack. It is, however, much used for mixing with copal varnish.

Benzoin is a gum-resin but little used in varnishes on account of its costliness. The finer sorts are brittle, pulverulent, with conchoidal fracture; they fuse at a gentle heat.

Colophony is synonymous with arcanson and resin. When the resinous juice of *Pinus sylvestris* and other varieties is distilled, colophony remains in the retort. Its dark color is due to the action of the fire. Dissolved in linseed oil or in turpentine by the aid of heat, colophony forms a brilliant, hard, but brittle varnish.

Copal is a gum-resin of immense importance to the varnish-maker. It consists of several minor resins of different degrees of solubility. In durability it is only second to amber; when made into varnish, the better sorts become lighter in color by exposure to air.

Copal is generally imported in large lumps about the size of potatoes. The clearest and palest are selected for what is called *body-gum*; the second best forms *carriage-gum*; whilst the residue, freed from the many impurities with which it is associated, constitutes *worst quality*, fitted only for japan-black or gold-size.

Copal is tasteless and inodorous; transparent and of conchoidal fracture. Heat softens it without rendering it viscid. In alcohol it is but little soluble; but it is said to become more so by reducing it to a fine powder, and exposing it to atmospheric influences for twelve months. Boiling alcohol or spirit of turpentine, when poured upon fused copal, accomplishes its complete solution, provided the solvent be not added in too large proportions at a time. The addition of camphor also promotes the solubility of copal; so likewise does oil of rosemary.

Dammara is a tasteless, inodorous, whitish resin, easily soluble in oils. It is not so hard as mastic, with which it forms a good admixture.

Elemi is a resin of a yellow color, semi-transparent,

and of faint fragrance. Of the two resins which it contains, one is crystallizable and soluble in cold alcohol.

Lac constitutes the basis of spirit-varnish. The resin is soluble in strong alcohol aided by heat. Its solution in ammonia may be used as a varnish, when the articles coated with it are not exposed more than an hour or two at a time to water.

Mastic is a soft resin of considerable lustre. The two sorts in commerce are, *in tears* and the *common mastic*; the former is the purer of the two. It consists of two resins—one of which is soluble in dilute alcohol. With oil of turpentine it forms a very pale varnish of great lustre, which flows readily and works easily. Moreover, it can be readily removed by friction with the hand; hence its use for delicate work of every description.

Sandarac is a pale odorous resin, less hard than lac with which it is often associated as a spirit-varnish. It consists of three resins differing as to solubility in alcohol, ether, and turpentine. It forms a good pale varnish for light-colored woods; when required to be polished, Venice turpentine is added to give it body.

Of the solvents of these various resins little need be said. In the manufacture of varnishes great care, as well as cleanliness, are required. The resins should be washed in hot water, to free them from particles of dust and dirt; they should be dried and assorted according to their color, reserving the lightest shades for the best kinds of varnish.

The *linseed-oil* should be as pale-colored, and as well clarified as possible. New oil always contains mucilage, and more or less of foreign matters; as these prevent the regular absorption of oxygen, the oil requires preliminary treatment. The common plan is to boil it with litharge; but such *oil varnish* is inferior to that prepared with sulphate of lead.

The best method is to rub up linseed-oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to the light and frequent shaking, the mucous deposits with the sulphate of lead, and leaves the oil perfectly clear. The precipitated slime forms a compact membrane over the lead, hardening to such an extent that the clarified oil may be readily poured off.

Turpentine is of very extensive use. The older it is, the more ozonized, the better it is. Turpentine varnishes dry much more readily than oil varnishes, are of a lighter color, more flexible and cheap. They are, however, neither so tough nor so durable.

Alcohol is employed as the solvent of sandarac and of lac. The stronger, *cateris paribus*, the better.

Naphtha and *methyiated spirit of wine* are used for the cheaper varnishes. Their smell is disagreeable. The former is, however, a better solvent of resins than alcohol.

SPIRIT VARNISHES.—Mix—

Alcohol	500 parts.
Ether.....	60 "

Heat in a flask, and suspend therein from a bag, one hundred and twenty parts of finely-divided well oxidized copal. Continue the heat until complete solution takes place.

Such a varnish combines brilliancy and transparency with considerable hardness and solidity. As color is easily generated over the fire, the materials are best digested in a water bath. Such a varnish is, however, only suitable for fancy articles, and is, after all, not equal to a mixture of resins.

A VARNISH FOR PAPER, MAPS, ET CETERA.

	Parts
Spirit of wine,	32
Mastic,	6
Sandarac,	3
Venice turpentine,	3
Pounded glass,	4

Mix the pounded mastic, sandarac, and glass thoroughly together, and place them in a tinned copper digester. Add the alcohol, stir well and frequently with a wooden spatula, and heat for several hours in a water bath. When the solution is complete, add the turpentine, stir frequently, continuing the heat for an hour, and strain when cold through a cloth.

This method is applicable to all spirit varnishes.

A WHITE SPIRIT VARNISH FOR VIOLINS.

Spirit of wine,	One gallon.
Mastic,	Two pounds.
Turpentine varnish,	One pint.

A VARNISH FOR WHITE WOODS.

Bleached shellac,	Three pounds.
Spirit of wine,	Two and a half gallons.

The shellac should be first dissolved in a gallon of the spirit, and the rest added after straining.

ANOTHER VARNISH FOR MUSICAL INSTRUMENTS.

	Parts.
Spirit of wine,	32
Sandarac,	4
Pounded glass,	4
Seedlac,	2
Mastic in tears,	2
Venice turpentine,	2
Elemi,	1

These varnishes may be readily colored—*red*, by dragon's blood; *yellow*, by gamboge. If a colored varnish is required, clearly no account need be taken of the color of the resins. Lac varnish may be bleached by Mr. LEMMING's process:—Dissolve five ounces of shellac in a quart of spirit of wine; boil for a few minutes with ten ounces of well-burnt and recently-heated animal charcoal, when a small quantity of the solution should be drawn off and filtered: if not colorless, a little more charcoal should be added. When all tinge is removed, press the liquor through silk, as linen absorbs more varnish; and afterwards filter it through fine blotting-paper. Dr. HARE proceeds as follows:—Dissolve in an iron kettle about one part of pearlash in about eight parts of water, add one part of shell or seed lac, and heat the whole to ebullition. When the lac is dissolved, cool the solution, and impregnate it with chlorine gas till the lac is all precipitated. The precipitate is white, but the color deepens by washing and consolidation. Dissolved in alcohol, lac bleached by this process yields a varnish which is as free from color as any copal varnish.

One word in conclusion with reference to all spirit varnishes. A damp atmosphere is sufficient to occasion a milky deposit of resin, owing to the diluted spirit

depositing a portion : in such case the varnish is said to be *chilled*.

ESSENCE VARNISHES.—They do not differ essentially in their manufacture from spirit varnishes. The polish produced by them is more durable, although they take a longer time to dry.

Table Varnish may be made as follows :—

Damma resin,	1 pound
Spirits of turpentine,	2 pounds
Camphor,	200 grains

Digest the mixture for twenty-four hours. The decanted portion is fit for immediate use.

COMMON TABLE VARNISH.

Oil of turpentine,	1 pound
Bees' wax,	2 ounces
Colophony,	1 drachm

COPAL VARNISH FOR INSIDE WORK.

Pounded and oxidized copal,	24 parts
Spirit of turpentine,	40 "
Camphor,	1 "

FLEXIBLE COPAL VARNISH.

Copal in powder,	16 parts
Camphor,	2 "
Oil of lavender,	90 "

Dissolve the camphor in the oil, heat the latter, and stir in the copal in successive portions until complete solution takes place. Thin with sufficient turpentine to make it of proper consistence.

OIL VARNISHES.—These, the most durable and lustrous of varnishes, are composed of a mixture of resin, oil, and spirit of turpentine. The oils most frequently employed are linseed and walnut ; the resins chiefly copal and amber, but also the others already recorded.

The drying power of the oil having been increased by litharge, red-lead, or by sulphate of lead, and a judicious selection of copal having been made, it is necessary, according to BOOTH, to bear in mind the following precautions before proceeding to the manufacture of varnish :—1. That oil varnish is not a solution, but an intimate mixture of resin in boiled oil and spirit of turpentine. 2. That the resin must be completely fused previous to the addition of the boiled or prepared oil. 3. That the oil must be heated from 250° to 300°. 4. That the spirit of turpentine must be added gradually and in a thin stream, while the mixture of oil and resin is still hot. 5. That the varnish be made in dry weather, otherwise moisture is absorbed, and its transparency and drying quality impaired.

The heating vessel must be of copper, with a rivetted and not a soldered bottom. To promote the admixture of the copal with the *hot* oil, the copal—carefully selected and of nearly uniform fusibility—is *separately* heated with continuous stirring over a charcoal fire. Good management is required to prevent the copal from burning or becoming even high colored. When completely fused, the heated oil should be gradually poured in with constant stirring. The *exact* amount of oil required must be determined by experiment. If a drop upon a plate, on cooling, assumes such a consistency as to be penetrated by the nail without crack-

ing, the mixture is complete ; but if it cracks, more oil must be added.

The spirit of turpentine *previously heated* is added in a thin stream to the former mixture, care being taken to keep up the heat of all the parts. With proper attention to these directions, the following prescriptions from DUMAS, TOMLINSON, BOOTH, and others will be found of use :—

COPAL VARNISH FOR FINE PAINTING.

Gum copal, fused,	8 pounds
Linseed oil, heated to 250°,	2 gallons

Boil for about a quarter of an hour, until the mixture strings strongly, and then add spirit of turpentine. In three gallons. Although much loss of turpentine ensues, the varnish will be so much the more transparent, durable, and drying.

CABINET VARNISH.

Copal, fused,	14 pounds
Linseed oil, hot,	1 gallon
Turpentine, hot,	3 gallons

Properly boiled, such a varnish will dry in ten minutes.

BEST BODY COPAL VARNISH.

Copal, fused,	8 pounds
Linseed oil, hot,	2 gallons
Turpentine, hot,	3½ "

The mixture must be slowly boiled for five hours until quite stringy, and subsequently mixed with the heated turpentine. This varnish is well suited for all objects intended for polishing.

In preparing *artists' copal varnish* it is advisable to separate the particles of copal by means of pounded glass, to prevent the gum from adhering, so that a moderate fire will suffice. The older the turpentine the more drying the varnish. Take—

Finest picked copal,	3 pounds
Pounded glass,	2 "
Linseed oil,	3 quarts
Spirit of turpentine,	5 "

All the before-mentioned varnishes are recommended to be made with clarified, but not otherwise prepared oils. Consequently they take long to dry, and cannot be polished for months. Anime is often introduced to hasten the hardening of the varnish, in the proportion of one part to two of copal. But such varnish is less durable. A yet inferior copal varnish contains anime in the proportion of two parts to one of the former.

WAINSCOT VARNISH FOR HOUSE PAINTING AND JAPANING.

Anime,	8 pounds
Clarified linseed oil,	3 gallons
Litharge,	½ pound
Acetate of lead,	½ pound
Sulphate of copper,	½ pound

All these materials must be carefully but thoroughly boiled together until the mixture becomes quite stringy, and then five and a half gallons of heated turpentine stirred in.

Such a varnish is, of course, every way inferior to one made with a carefully prepared drying oil, as above prepared by the aid of sulphate of lead. But it exsiccates very rapidly, and is well suited to the common purposes

for which it is intended. It can be easily deepened in color by the addition of a little gold-size.

The varnish used in India for palanquins is made by melting a kind of sandarac, and mixing it with boiling and drying linseed oil. Mr. RHODE, in *Balfour's Cyclopædia*, knows of no better or more durable polish for teak and chittagong wood particularly, than may be prepared by melting three or four bits of sandarac, of the size of a walnut or small egg, and pouring upon it a bottle of boiling linseed oil previously rendered drying by boiling litharge or other dryer, and after boiling them together gently for an hour, adding while cooling a teaspoonful of venice turpentine. If too thick, it may be thinned with spirit of turpentine. It should be rubbed on the furniture, and after a little time—during which it may be exposed to the sun—rubbed off. The friction should be continued daily, and the polish should not be again applied for eight or ten days; after which it may be slightly applied every one or two months. Water does not injure this polish, and any stain or scratch may be rubbed over, which cannot be done with French polish. To give the appearance of gold to silver leaf used by the Condapilly Moochies, for ornamenting boxes, palanquins, *et cetera*, a little aloes is dissolved in the varnish, which is laid over it. A very good varnish is prepared by Moochies with shell-lac and wood oil, heated in small quantities.

French polish is employed upon flat surfaces, and consists simply of a solution of resin in spirit of wine. The simplest sort of French polish may be made by dissolving one and a half parts of shell-lac in eight parts of spirit of wine. Such a polish is very durable, but many other gum-resins are employed. A good dark-colored polish is prepared from one pound of shell-lac, half a pound of gum-benzoin, and one gallon of spirit of wine. Others recommend twelve ounces of shell-lac, three ounces of copal, six ounces of gum-arabic, to one gallon of spirit.

The *lacker* used for wood work or brass is also a varnish. For brass the proportions are half a pound of pale shell-lac to one gallon of spirit of wine. It is better prepared without the aid of heat, by simple and repeated agitation. It should then be left to clear itself, and separated from the thicker portions and from all impurities by decantation. As it darkens on exposure to light, the latter should be excluded. A pale yellow *lacker* may be made by mixing one ounce of gamboge, and two ounces of Cape aloes, with one pound of shell-lac. For a bright yellow half a pound of turmeric and two ounces of gamboge are required; for a red *lacker*, half a pound of dragon's blood and one pound of annatto. It need scarcely be said that the color will also be modified by that of the lac employed.

WATER.—*Eau*, French; *Wasser*, German; *Aqua*, Latin.—The poet SOUTHEY thus appositely writes of this all-important fluid:—

Most blessed water! neither tongue can tell
The blessedness thereof; no heart can think,
Save only those to whom it has been given
To taste of that divinest gift of heaven.

In the very first record of that fiat of the Creator, which called forth by omnipotent volition the innu-

merable planetary bodies distributed in infinite space; the primary matter especially mentioned is water: *And the Spirit of God moved upon the face of the waters.* Whether the circumstances of the creation, as related in Genesis, differ from the order observed in giving form to, and producing diversity of, objects upon the earth by the *great First Cause*, is a question which does not affect one way or another, the subject of the present article; although the study of the disposition of the principal objects within the limited range of man's sphere of inquiry, geographically and geologically considered, demonstrates most conclusively, that water has fulfilled functions in the formation of mineralized and other strata in the solid crust of the earth, of undeniable importance. It is not previous to the generation of vegetal and animal life, however, that the importance of water, as an abundant and primary constituent of the globe, can be properly estimated; for it is only in the fulfilment of the higher designs of Providence, such, for instance, as the production and sustenance of vegetal and animal life and organization, that any approach to an adequate notion of the great ends which water serves, can be formed. Without water no organized structure, whether of vegetal or animal, could, in the human estimation of things, preserve its functions and reproduce itself in obedience to the great generic law of Nature. Independently of its essential importance in this respect, water serves another purpose only secondary to it—namely, that of distributing a medium temperature over the whole surface of the earth, conformably to certain physical laws which will be subsequently alluded to, thereby insuring a genial warmth which is absolutely necessary for the development of plants and animals. It may be assumed, that for some such or other similar all-wise dispensations, the extent and quantity of water on the globe greatly surpasses that of the land. It is well known that water is capable of combining with caloric to a great degree; and, owing to the superficies of the globe being to the extent of two-thirds, water, it is evident the chief portion of the heat derived from the sun is stored in this liquid, for the purpose merely of being eliminated gradually to compensate the earth for that which, owing to its superior radiating power, it gives off so freely as to chill it to a degree prejudicial to organized life, unless supplied by winds or air-currents, passing over the surface of large tracts of waters. This capacity of storing caloric possessed by water is subservient in other respects, not only for equalizing the heat of the habitable portions of the globe, but for the distribution of the liquid itself over the arid parts of the earth. For instance, the warm rays of the sun would be unendurable in the torrid zone, were it not that in these regions large quantities of water are evaporated, and that every unit of it thus converted into vapor renders latent or insensible above one thousand units of heat, thus beautifully neutralizing the violent effect of the sun's intense rays. Again, the aeriform moisture ascends obedient to its expansive force, and diverges laterally to colder regions, where the water having parted with a great portion of its acquired temperature, condenses into clouds, and finally falls as rain, hail, or snow, to refresh and nourish life in its multifarious varieties;

whilst a current of air from colder regions loaded with water rushes to the locality whence it was driven, to compensate the loss of moisture, and maintain the equilibrium of temperature. Thus is a beautiful provision for the preservation of organic life and the maintenance of a genial warmth sustained, a provision which, from its regularity and precision, is called a physical law, though in reality a divine and beneficent dispensation.

Water is therefore of primary importance as well in the physiology as in the economy of life, and quite as indispensable as the air breathed from the dawn to the close of man's existence; without them all other provisions of nature would, under existing circumstances, be inadequate to sustain vitality.

HISTORY.—In considering water scientifically, it offers a wide and an interesting field of inquiry to the aspiring student. For a long time many earnest minds were misled regarding its nature, nor was it till almost within the span of the present age—namely, in 1781—that its true composition was revealed. Formerly, philosophers, universally following the footsteps of the ancients, regarded it as one of their elements, though, in later times, some among them were found who considered it transmutable into an earth by repeated distillations, in consequence, as LAVOISIER subsequently proved, of the glass vessels in which the operations were performed, undergoing slight disintegration on the surface, and giving rise to a crust of silicious and other matters contained in the glass. Its real nature lay hidden and subject to conflicting hypotheses till, by the superior powers of deduction, aided by a deep and patient penetration into the secrets of phenomena, according to the principles of chemistry as then understood, CAVENDISH, by most conclusive and beautiful researches, as well synthetically as analytically, revealed its true nature as a compound body. Like all other inventions and discoveries of great importance, there were others ready to claim the honor, such as WATT and LAVOISIER; but evidently the principles which they enunciated appear to have originated with CAVENDISH, and had been communicated through PRIESTLEY and others to the forementioned philosophers, previous to the publication of the account of CAVENDISH's researches on the subject. The light thus shed upon the knowledge of chemical phenomena, might appropriately be placed in juxtaposition with the brilliant lustre emanating from the discovery of oxygen by a PRIESTLEY, or from that of the atomic theory by a HIGGINS and a DALTON. The phenomena attending the combustion or explosion of hydrogen gas in common air, and the endeavors of WARLTHIRE to deduce from the experiment whether or not caloric was ponderable, seem to be the primary facts that led subsequently to the discovery of the composition of water. PRIESTLEY, WARLTHIRE, and doubtless others, too, repeated the experiment frequently; and although water was a product in every instance, yet no one before CAVENDISH seems to have given the necessary attention to the question of how this water was formed. After numerous trials regarding the proportions of air and hydrogen that were required to produce this important liquid, CAVENDISH found these to be two volumes of hydrogen and five

of air. Subsequently the research in this direction recommended itself to other philosophers, among whom GAY-LUSSAC fixed the respective quantities of the component gases necessary to produce water at one volume of oxygen and two of hydrogen.

PREPARATION.—When two volumes of hydrogen and one of oxygen gas are mixed in a confined vessel and ignited by means of the electric spark, a slight flash of light and loud explosion follow their combination, and water remains in the vessel to the extent of the weight of the combined gases. In like manner, when hydrogen issuing from a small jet is ignited, and a deep cylindrical glass is inverted on the flame, water is produced; and, owing to it being condensed on the cold surface of the glass, appears first as a slight coating of dew, and subsequently in the form of small drops which trickle down the walls of the vessel. Many other means are now known, whereby pure water from its elements is produced, such, for instance, as transmitting pure hydrogen gas over several metallic oxides inclosed in tubes, and heated to redness. The most conclusive experiment for demonstrating the composition of water is that performed by the aid of the galvanic battery. In this experiment, the constituent gases are evolved at the respective poles of the battery in the ratio of two volumes of hydrogen and one of oxygen; and by mixing these gases in a eudiometer or other tube, and transmitting the electric spark through them, water is again reproduced. It would be tedious to specify the numerous ways in which water can be formed from the combustion of hydrogen. It may be instanced, however, that finely-divided platinum—platinum black—possesses the power of causing the combination of the gaseous constituents of water in a remarkable manner. The principle of DOBEREINER's instantaneous light is founded on this same property.

The arrangement by which the decomposition of water may be illustrated, consists simply of a glass globe with stopper openings at the sides and at the top, filled with water. Small platinum wires pass through the corks at the sides, and up through the apertures at the top, terminating in flat plates of the same metal. Two graduated tubes filled with water are inverted over these plates, and the zinc and copper poles of a voltaic battery connected with the protruding wires at the side, thus converting the two tubes into ordinary decomposing cells. On setting the battery in action, the water in the tubes will undergo decomposition in part, oxygen being formed on the side of the copper or positive pole, and hydrogen on that of the zinc or negative pole: both gases, as they accumulate, ascend to the closed ends of the tubes, forcing out the water. By reading the index on the tubes, it will be found that the quantity of hydrogen in the tube inverted on the zinc pole will be strictly double the volume of the oxygen in the other; in other words, the elements are evolved in the exact ratio of their existence in water, as may be proved experimentally by exploding the mixture of both gases in a cylinder over mercury.

PROPERTIES OF WATER.—Water, like gases and elastic bodies generally, possesses very varied properties both of a physical and a chemical nature. The knowledge of the former constitutes the chief division

of two correlative branches of the physical sciences, namely, hydrostatics and hydrodynamics; the former relating to the equilibrium, or the statical momentum of this fluid, and the latter, to the order of its motion under unequal forces. As the knowledge of these is more particularly connected with the science of mechanics or engineering, they need not be specially dwelt upon here.

Pure water has neither taste nor smell; it is colorless in small bulk, but of a greenish hue when seen in large masses. Water is solid at temperatures below 32° , liquid between 32° and 212° , and gaseous at a higher heat. By a careful method of reducing the temperature of water, and guarding against any agitation of the liquid or contact with any angular body, the point of solidification descends as low as 8° , or even 5° ; that is, 24° and 27° below the point at which it freezes when it is agitated. In like manner, if the ordinary pressure under which it boils at 212° , namely, thirty inches of mercury, be reduced, the phenomenon of ebullition succeeds at considerably lower degrees of heat. Thus it is that on the summit of high mountains, where, in consequence of the elevation, the normal pressure of the atmosphere is lessened, water is observed to boil at a lower thermometric degree than at the base. In the act of solidification water resolves itself into numerous forms, one of which is a rhomboid, closely resembling Iceland spar. Under ordinary circumstances, when its particles are in equilibrium, water is elastic and compressible. This property had long since been proved by OERSTED, and modernly has been established by PERKINS. The results are, however, variously stated: thus, PERKINS found that by a pressure of three hundred and twenty-six atmospheres, the compression amounted to $\cdot 035$ of the bulk, or a value of one hundred and eight millionths for every atmosphere; whereas, when the strain was raised to two thousand atmospheres, the reduction was less than one-half of the above for each atmosphere, namely, forty-one millionths. OERSTED found the average reduction per degree to be forty-five millionths of its bulk; he likewise observed that the contraction increases in direct proportion to the power exercised in compressing it, up to seventy atmospheres. Water is likewise subject to compression and extension when under the influence of another power, namely, that of heat, but with greater irregularity than is observed when acted upon by mechanical force. Generally speaking, the abstraction of heat from bodies serves to bring their particles closer together, and therefore contract them, and *vice versa*; but the axiom is true with regard to water only within certain limits. For instance, when ice is melted by causing it to combine with caloric, instead of expanding with each increment, its bulk suffers a diminution till the temperature of the mass rises to $39\cdot 2^{\circ}$, at which degree it has been found to possess its greatest density; on continuing the addition of heat, however, it begins to expand till the boiling point is attained, the acquired bulk in this range being, according to the researches of HALSTROM, one part in twenty-four. The experiment can be easily illustrated by a glass vessel fitted with a narrow tube; the contraction and expansion of the water in the flask being indicated by its descent or rise in the capillary

tube inserted into its mouth. The peculiarity attending a change of temperature in water, between the limits of 32° and 48° may be shown to vary from the expected effects resulting under ordinary circumstances from the addition or abstraction of caloric; thus, the expansion which is observed to take place in the liquid from its point of greatest density, $39\cdot 2^{\circ}$, when heated through a range corresponding to that between this and the freezing point, equals exactly that which a reduction of temperature from $39\cdot 2^{\circ}$ towards the freezing effects, so that the volume at 48° and 32° is exactly the same.

The following table of the contraction and expansion of water between the three points, 32° , $39\cdot 2^{\circ}$, and 212° , gives the results arrived at by KOPP:—

Temperature.	Volume.	Temperature.	Volume.
32.0	1.000000	69.8	1.001776
33.8 ....	.999947	71.6	1.001995
36.5 ....	.999908	73.4	1.002225
37.4 ....	.999885	75.2	1.002465
39.2 ....	.999877	77.0	1.002715
41.0 ....	.999883	86.0	1.004064
42.8 ....	.999903	95.0	1.005697
44.6 ....	.999938	104.0	1.007531
46.4 ....	.999986	113.0	1.009541
48.2	1.000048	122.0	1.011766
50.0	1.000124	131.0	1.014100
51.8	1.000213	140.0	1.016590
53.6	1.000314	149.0	1.019302
55.4	1.000429	158.0	1.022246
57.2	1.000556	167.0	1.025440
59.0	1.000695	176.0	1.028581
60.8	1.000846	185.0	1.031894
62.6	1.001010	194.0	1.035397
64.4	1.001184	203.0	1.039094
66.2	1.001370	212.0	1.042986
68.0	1.001567		

This peculiar behavior of water is not only interesting as a curious deviation of a natural law, but because it serves purposes of the highest importance in the economy of Nature. The hardest rocks are split asunder by the freezing and expansion of the water which penetrates their fissures, soils are disintegrated, and their hidden elements of nutrition presented in a state fit for absorption by the roots of plants.

When the great body of water of the globe is cooled on the surface, the exposed portion, owing to its density being slightly increased, sinks, causing the warmer substratum to rise, to manifest the same behavior when its temperature is lowered in like manner. Did this circulation continue till the entire mass acquired a freezing temperature, it is evident that the whole body of water would enter nearly at once into the solid state of ice, to the destruction of all living creatures inhabiting it, to the destruction of oceanic commerce, and of the communion of peoples separated by large tracts of oceans and seas. Further, were such the order of the laws governing Nature, not only would the living inhabitants of waters inevitably perish, but those on the land would also be destroyed, in consequence of the insupportable cold that would be produced in the atmosphere, owing to another property which water, whether in the liquid or solid state possesses, of combining with heat, and rendering it latent or insensible. The warmest seasons would be of little avail to counteract such dire effects, and the genial climate of temperate zones would be changed to a far worse condition than

the frigid regions of the North pole! Providentially, however, the progress of the cooling and consequent circulation induced in water by cold is arrested when the whole mass reaches a temperature of about 40° , that is, 8° above the freezing point; for at this limit, instead of contracting and sinking it becomes specifically lighter by expansion, and therefore remains floating on the subjacent mass. By a continued reduction of its temperature the surface will ultimately freeze, and the crust of ice may go on thickening; but it is inconceivable what cold could thus convert the entire mass into the solid form in this way. Hence, even in the perpetually frozen regions of the North, the water beneath the ice retains a heat of 40° —a temperature much higher than is experienced in this climate often during Winter—and suited not only to marine animals, but calculated, under the least favorable change, to aid in bringing about the normal state of things best suited to the wants of the great family of God's creatures.

From the preceding remarks, the cause of ice—solidified or crystallized water—floating in water will be readily understood. It has been shown that at the point of solidification the liquid has the same, if not a lesser density than at 40° ; but, in passing to the solid state, the gravity is much further reduced, as well by the arrangement which its particles assume, as by the expulsion of the gases dissolved in the water, and which, before they can escape, are enveloped and compressed within the solid crystal. From both, and perhaps other conjoint causes, the density of ice at a temperature of 32° is less than that of water at 212° , and hence the former floats in the latter. At the normal degree at which chemists are accustomed to compare the densities of bodies, namely 60° , and a barometric pressure of the atmosphere of thirty inches, pure water is taken as the standard of comparison, and is expressed by unity, or 1000—compared to this ice has a density of 0.916.

Another circumstance which prevents the freezing of the waters of the oceans is the quantity of saline matters which they hold. DESPRETZ found that all such saline solutions have a point of maximum density, which is so far below 39.2° as the solution is richer in salt, and this point of maximum density is even below the freezing point of these solutions when agitated, although in a quiescent state they may be cooled below it without assuming the solid form. The following are the results of his researches on this subject, with solutions of 3.759 parts of the undermentioned compounds in one hundred of water:—

	Maximum density.	Freezing point
Potassa,.....	21.80	28.22
Carbonate of potassa,.....	24.89	26.22
Sulphate of potassa,.....	27.90	28.24
Carbonate of soda.....	19.38	26.87
Sulphate of soda,.....	24.21	27.84
Chloride of sodium,.....	24.45	27.02
Chloride of calcium,.....	26.95	26.95
Dry sulphate of copper,....	30.89	29.63

In considering the effects of heat upon water, a further insight into the beautiful provisions of Nature may be obtained. It has been stated in the preceding that water is the medium by which the great heat of warm climates is assuaged. Here it may be well to explain a little more fully how this is effected. Water, of all

known substances, has the greatest capacity for heat—that is, its power of combining with this imperderable, and exhibiting in a less degree its effects at point of warmth than any other body. This property is possessed by it in its several forms of solid, liquid, and vapor or steam. If a given weight of ice, indicating a temperature of 32° be added to an equal bulk of water at 135° , and the mixture be left at rest till the former is melted, the temperature of the mixture on being essayed will not be the mean of the two degrees of heat— 83.5° —as might be anticipated, but it will be found at the same standard as that of the ice itself before its introduction to the hot water. Hence it is evident that ice, or water, in passing from the solid to the liquid state, renders latent as much sensible heat as would bring it to about half the temperature of boiling water, were it in the liquid state at 32° ; or within 52° of boiling water, were it at the normal temperature of 60° . REGNAULT's results on this subject are 142.6° , as the amount of heat rendered latent by water in passing from the solid to the liquid state. All this latent heat is evolved from the water in passing to the solid state of ice; and thus does it beautifully serve to soften the rigor of the cold necessarily felt by those in polar climes. In its liquid state, between 32° and 212° , water manifests the same power of uniting with heat, and showing less of its effects sensibly than any other body. For instance, when a pound weight of water at 100° is mixed with the same weight of itself, of olive oil, and of mercury respectively, at 40° , it will be found that the temperatures of the resulting mixtures will not be the same: the mixture of the waters will show the exact mean of their respective heats before mixing, that is 70° ; but that of the water and oil will be 80° , and of the mercury and water will be 98° . Hence it will be seen that the same quantity of heat which in the last instance produced an effect of 2° on water, raised the same weight of mercury 58° ; and that of 20° in the case of the mixture, water and oil, equalled an effect of 40° on the oil alone. The consequences of this capacity for heat are most important in retaining the temperature of bodies at a medium point, and its value to the human frame in hot climates is almost incalculable; for when taken into the system, or evaporated from the parched and inflamed skin of the inhabitants of dry and arid countries, it reduces the heat of the system more than the same weight of any given substance.

When water is evaporated, the caloric which is thus carried off, and with as little sensible effect as that absorbed by the ice during its transition from solid to a liquid, is very great. Water may be boiled in a vessel, and although heat is transmitted to it, during the period of its evaporation, in a continuous stream, yet the heat of the liquid does not rise beyond 212° , nor does the vapor exceed the same; necessarily, therefore, the whole of the caloric absorbed must be rendered latent in the vapor formed. This may be proved to be the case by transmitting a given weight of the vapor of water—steam—at 212° into a measured bulk or weight of water at any degree, such for instance as 32° or 60° , and noting the effect. In this way it has been found by DULONG to contain as much as 977.4° of latent heat, which, added to its sensible

calorie, 180° —the difference between 32° and 212° —gives a total of 1157 degrees, or units of heat, possessed by every unit of water in the form of steam at 212° . Without dwelling upon the importance in an industrial point of view of this property which water possesses of combining with heat on assuming the gaseous form, and parting with the same wherever this vapor is transmitted to and condensed, or on the power which an accumulation of the vapor at its normal temperature, or at a higher heat, exercises in the thousands of varied forms in which steam is employed in connection with mechanism and industrial works of arts and manufactures—it will be well to cite this property in further proof of the profound beauty of the conception which, as stated in the introduction, has ordained this to be the medium of modifying the rigor of seasons and the influence of the geographical position of lands. Thus the water which is evaporated within the tropics, and which takes up with it an amount of heat corresponding to 1100° , conveys this heat towards the frigid zones, where, on being condensed either into rain, hail, or snow, it is given out to the air and surrounding objects, and thereby greatly contributes to the mildness and habitableness of those parts. Water evaporates not only at 212° , but at all intermediate temperatures between this and its freezing point; and even when in the state of ice, it has been ascertained that it gives off a very rarefied steam. In all these cases the quantity of heat which it renders latent increases with the degree of rarefaction, so that the same weight of steam, or watery vapor, produced at 60° , contains much more insensible heat than when generated at the boiling point of water.

The chemical relations of water are likewise of the utmost importance. In solvent power, that is, its power of overcoming the cohesion of particles of matter, it has no equal; and this force is exercised in reference to gases and liquids, as well as solid bodies; only that in the case of gases, instead of overcoming the cohesive force of the substance, the reverse is the effect, for it is the repulsive force or their expansion that is, so to speak, neutralized. To this phenomenon of destroying the repulsive force of the particles of gases, and the cohesive in solids or liquids, the term *solution* is applied; and, as is well known, it can in some cases be effected by heat, although in these the change is properly designated *fusion*. Water does not manifest the same behavior, however, with all solids, liquids, and gases, so that it appears the particles of the body capable of being affected in this way, must have a peculiar state of molecular aggregation which holds them together with a force inferior to that which water exerts upon them. There are therefore a numerous class of substances that are not affected at all under ordinary circumstances, and others to a very unequal degree, by water in this respect. For instance, a piece of rock crystal, calcareous spar, or glass, will remain in water a length of time without undergoing any change; but a crystal of sugar-candy, alum, or carbonate of soda, will be found to disintegrate readily, and disappear in the liquid. The former are said to be *insoluble*, and the latter *soluble* substances, in reference to water. Of those which are soluble in water, the quantity of them

which the liquid is capable of combining with, till the equilibrium of the cohesion of the substance dissolved is attained—in other words, the point of saturation of the liquid with such a compound, is very variable, though almost in all cases more or less increased by heat. This may be readily proved by adding to equal weights of water, sugar, salt, or chloride of sodium and gypsum, exposing as great an extent of these as possible to the water by stirring the mixture, and then permitting to rest a while. If the solutions, say one pound of each, be evaporated, and the dry residue weighed, it will be found that the saccharine matter will weigh about twelve ounces, the saline residue about five and a quarter ounces, and the calcareous not more than fourteen or fifteen grains. Again, difference of temperature affects the solvent power of water, increasing it—except in few instances, such as when common salt and gypsum are the subjects, and which are nearly equally soluble in cold and hot water—with each additional degree of heat communicated to the liquid up to 212° ; thus nitrate of potassa is dissolved in water at 57° to the extent of one-fourth, at 92° to that of one half, at 131° to an equal weight, and at 212° to the extent of twice the weight of the water employed. When the solutions made at the higher temperatures, however, are allowed to cool, the particles of the solids, over and above what is taken up at the normal degree, regain their cohesive force, and separate in the form of crystalline bodies. These reactions are of particular importance in a chemical point of view, as they offer a simple and ready means of separation and purification of many substances in various branches of manufacturing industry, the principles of which are governed by chemical laws. Another phenomenon connected with the solution of solids in water is, that in several instances a reduction of temperature takes place; while in other cases heat is evolved. GAY-LUSSAC has explained this anomaly. He found that when simple solution was effected of a salt, whether in a hydrated or anhydrous state, cold, or a reduction of the temperature of the liquid, resulted; but when chemical combination took place between the substance and the solvent, as, for instance, in the production of a definite hydrate, a rise of temperature is experienced. In the former case the salt, in passing from the solid to the liquid form, renders a quantity of heat greater or less according to its capacity for this imponderable, latent, and which is abstracted from the sensible temperature of the water; whilst in the latter the chemical force exerted in the act of combination develops an amount of caloric which is greater than that of the latent heat of the body, and hence the rise of temperature. The simple experiment of dissolving nitrate of potassa or chloride of ammonium in water will, with the aid of an ordinary thermometer, illustrate the truth laid down to the reader as regards the cold produced; and of hydrate or caustic potassa or sulphuric acid in reference to the heat developed. This reaction affords a ready means of distinguishing between chemical combinations with, and simple solution of a substance in water. In all these cases, however, with the exception of simple combination, water effects no change in the substance, so that by evaporation of the liquid, the solid

matter may be again obtained, possessing the properties peculiar to it before solution. There are a few instances, however, in which water does not retain this neutral character; for with some of the salts of bismuth, antimony, and tin, its addition produces a decomposition, causing a liberation of the radical or acid of such, while itself in part undergoes decomposition. The reader will find these examples of decomposition illustrated under the respective metallic salts referred to.

To enter into the behavior of water with the alcohols, ethers, oils, resins, and other matters, would prolong the subject beyond prescribed limits; suffice it to say, that when alcohols partake of the nature of oils, they are not at all soluble in it; neither are ethers and oils, in the ordinary acceptation, dissolved by water; nor are the resins. Alcohol—that resulting from the fermentation of saccharine matters—is soluble in it in all proportions, although ether, the derivative of this body, and differing from it only by the elements of one equivalent of water, is almost insoluble in the liquid.

Behavior of Water with Gases.—Not only has water the property of liquefying a great number of solid bodies, but it exercises the same function with respect to many gases; a property that is of very great importance in the economy of nature in many instances.

To convey an adequate conception of the solvent power of water for gases, it may be stated that one hundred cubic feet, or six hundred and twenty-five gallons of water, at 60° and a barometric pressure of thirty inches, will dissolve of—

Hydrochloric acid gas,.....	50000.0	cubic feet.
Ammonia,.....	67000.0	"
Sulphurous acid,.....	5000.0	"
Sulphuride of hydrogen,....	300.0	"
Chlorine,.....	200.0	"
Carbonic acid,.....	100.0	"
Carbonic oxide,.....	6.6	"
Binoxide of nitrogen,.....	5.0	"
Oxygen,.....	4.6	"
Nitrogen,.....	2.5	"

Water which has been much exposed to the air, such as rain water, absorbs two and a half parts of that compound; and what is so curious regarding it is, that the amount of oxygen in such, instead of being only twenty-one per cent., as in the atmosphere, was found to be so high as 34.8 per cent. by GAY-LUSSAC and HUMBOLDT. BOUSSINGAULT found that at an elevation of six to eight thousand feet, water absorbs not more than one third of the volume of air which it liquefies on the plain; which behavior has been cited as the cause of fishes not being found in the Alpine lakes situated at comparatively high altitudes; the small amount of oxygen in the soluble state in the water being thought insufficient to support the respiration of these cetaceous animals.

Many natural waters contain considerable quantities of nitrogen. PLAYFAIR estimated that the famous Buxton water, as it issues from the spring, is in combination with nearly three-fourths of its volume of nitrogen—as will be hereafter more discussed under its analysis. With so unnatural a phenomenon, the question, Whence does it come? at once intrudes itself. That it is assimilated from the air is impossible; and it is hardly conceivable that the water in passing through

the calcareous strata of the district should meet with or take up such quantities of nitric acid and ammonia as would, by their mutual decomposition in some such manner as the following—



give rise to the forementioned volume of gas.

Before entering upon the consideration of natural waters with respect to their hygienic qualities, *et cetera*, it may be stated that pure water at 62° and thirty inches barometric pressure, is taken for the standard to which the relative density of all other solids and liquids is compared; just as air is adopted as the standard for measuring the gravity of gases, both being assumed unity, or 1000. At the above degree of heat and pressure, one hundred cubic inches of it weigh 252.45 grains; consequently the imperial gallon weighs 70.000 grains, or ten pounds avoirdupois. It is eight hundred and fifteen times heavier than air, and one thousand three hundred and four times the weight of an equal bulk of its densest vapor, steam, generated at 212°. Its composition is represented as being one equivalent of hydrogen and one of oxygen—HO—and it has been found to contain—

	At. weight.	Centesimally
1 Eq. hydrogen,.....	1	11.1
1 Eq. oxygen,.....	8	88.7
	<hr/> 9	<hr/> 100.0

NATURAL WATER.—By this term is understood the ordinary liquid which serves the purposes of every-day life, whether its source be the rain, hail, or snow, which falls from the atmosphere; the drainings of the surface of the country, accumulated in lakes or rivers; well, or natural springs, through which the liquid permeating the porous strata of the earth at one place, finds an outlet or lower hydrostatic level at another; and sea or salt water. For the sake of clearness in the details which the Editor intends to lay before the reader on this subject, its consideration will be made in the following order, namely, rain, surface—including lakes and rivers—and spring or well waters, all embraced under the class Fresh Water; and Sea Water, or such waters as contain an abnormal quantity of foreign ingredients, and are therefore unfit for the more general uses to which this liquid is applied.

FRESH WATERS.—*Rain and other Waters immediately derived from the Atmosphere.*—As already stated, there is a continual evaporation of water taking place from the surface of the land and sea, which is greater in warm latitudes, and lesser in the parallels approaching the frigid zones and the poles of the earth. This evaporation is dependent, in the first instance, on that curious property of gases, discovered by DALTON, by which a space filled with one kind of vapor or gas, offers as little obstruction to the diffusion of another vapor or gas, in the same space, as if it were already a vacuum, and in the second, upon the temperature. Some other conditions likewise affect the evaporation of water spontaneously, such as the quantity of moisture already contained in the atmosphere, the force and direction of the winds, *et cetera*, which need not be followed. Whilst the heat at which it

was converted into an elastic vapor remains the same, watery vapor is quite as invisible as the air; but on sudden changes of temperature, occasioned by being brought into contact with a colder body of air, or any cooling surface, then the moisture is first condensed into very minute drops, forming clouds, and these drops continue to aggregate among themselves till their gravity becomes greater than the air, and they fall to the earth as refreshing rain. The theory of HUTTON, with respect to rain being produced by the mixing of opposite currents of air at different temperatures, though true to some extent, appears to be inadequate to produce the amount of rain which the numerous meteorological observations so generally made during late years have registered; and it is therefore supposed that more rain is formed in close proximity to the earth, than in the higher regions of the air. The experiments of Professor J. PHILLIPS corroborate this in an extraordinary manner. He found that the fall of rain on the—

Top of York Minster, 242 feet high, was	15·910 inches.
Roof of Museum, 73 "	20·461 "
Surface of ground, 0 "	24·401 "

That all the rain of these latitudes could not be produced on Dr. HUTTON's principle, may be readily conceived by considering the circumstances a little in detail. The tension of the vapor of water at 59° equals 0·5000 of an inch of mercury, and at 41° 0·2573; now, if equal bulks of air at these temperatures, saturated with water, commingle, the mean temperature of 50° will be attained, at which the tension of the aqueous vapor is 0·3608, the difference between which and 0·3786, the mean of the tensions above indicated, that is, 0·0178, represents the tension of the amount of water that would be condensed from the state of vapor. This quantity is very inconsiderable compared with that resulting from atmospheric changes which take place on or near the earth, as may be seen from the following example, quoted from GRAHAM. The mean temperature of January in this country is about 34°, but with a South-west wind the thermometer may be observed to rise gradually in the course of forty-eight hours to 54°; now, supposing such wind to be saturated with aqueous vapor, and that in traversing over the surface of the land it is cooled to 34°, the amount of moisture which it must deposit will be very considerable, as appears by the following—

Tension of vapor at 54° equal to	0·429 inches mercury.
Do. do. 34° "	0·214 "
Difference condensed as rain,	215 "

Invariably there is the greatest average fall of rain near the equator; it diminishes towards the poles, as the latitude is higher. The average annual fall of rain at—

New Granada, 12° 0' N.....	is 126 inches.
Calcutta, 19° 46' N.....	81 "
Rome.....	39 "
England, average.....	31 "
London.....	23 "
St. Petersburg.....	16 "
Uleaborg.....	13½ "

¹ Snow and hail is a form of rain, in which the water is frozen before it reaches the earth; the former results from the formation of clouds at temperatures below 32°, wherein the minute drops are crystallized into an infinity of spicules, which arrange themselves into regular lines and figures, diverging from one another at angles of 60° and 120°. They are all referable, however, to the hexagonal and prism shape, though the details differ in almost every storm.

Hail is supposed to be formed in warm weather, when the sun is above the horizon, and under different circumstances to those calculated to produce snow. It is supposed to be produced in the ascending current of greatly rarefied air, by the cold consequent on such rarefaction, the force of the upward current being such as to carry with it the minute solid globule, till, by uniting with others, it attains a density that causes it to descend. Generally, this phenomenon of the production of hail is associated with a peculiar electrical state of the atmosphere, to which it must be principally attributed.

Rain, as it descends from the clouds, is contaminated with various gases and vapors which it dissolves from the air. The atmosphere, normally composed of oxygen and nitrogen, contains vast quantities of ammonia, carbonic, nitrous, and nitric acids, besides other gases and vapors which arise from the number of chemical phenomena which are ever taking place on the surface of the earth. The principal of the *abnormal* gases is *carbonic acid*—a gas which escapes in enormous quantities from volcanic districts, and which results also from respiration, from the combustion of fuel, and decay of organic matter and vegetal growth generally, on the surface of the earth. Though analysis detects only about one thousandth of this gas in the air, still when the total bulk of the latter is taken into consideration, the entire weight of carbonic acid disseminated in it is enormous, averaging more than *five billions of tons!* The air likewise contains much ammonia and vapors of the oxides of nitrogen, besides other unknown gases and vapors, which escape from decomposing animal and vegetal matter.

All the gases which have been detected in atmospheric air are exceedingly soluble in water; hence it follows, that rain-water, as it descends through the lower strata of the air, must become to a great extent impregnated with these gases. LIEBIG has shown that even snow contains much ammonia, and recently in some rain-water, collected on Brighton Downs, MEDLOCK detected this gas, and also traces of the acids of nitrogen, which had probably resulted from the oxidation of a portion of the volatile alkali. It is, therefore, evident that water as it falls from the clouds, whether in the form of snow or rain, is not absolutely pure, but contains much carbonic acid and ammonia. Probably traces of other gases, which have hitherto eluded detection, are likewise present. Not only is ammonia present in snow and in rain, but HORSFORD even detected it in large quantities in the ice from the Glacier de Boisson, at a height of twelve thousand feet above the level of the sea; and MEDLOCK has found marked quantities of this volatile alkali in the purest and most transparent masses of ice from the Wenham Lake in

America. The presence of ammonia in rain-water has not long been known; and it is one of the main causes of the fresh and invigorating influence of it upon the vegetal creation.

SURFACE WATER.—Rain-water is a very powerful solvent of certain ingredients of the soil, such as sulphate of lime, chloride of sodium, and magnesian salts; but when saturated with carbonic acid, as is ordinarily the case, its solvent properties are remarkably increased. For example, ordinary water, free from carbonic acid, will not dissolve more than a grain of chalk per gallon; but when saturated with that gas, the same quantity will dissolve upwards of two hundred grains. In like manner it is found that carbonate of magnesia, which is almost entirely insoluble in ordinary water, will dissolve in water impregnated with carbonic acid in very considerable quantity. Hence, in addition to the alkaline chlorides and sulphates, and sulphate of lime, nearly all spring-waters are found to contain carbonates of lime and magnesia, which are held in solution as bicarbonates by the carbonic acid derived from the soil and atmosphere. Certain of the mineral constituents impart to water its *hardness*. These are the salts of lime and magnesia. By the hardness of a water is understood the power it possesses of decomposing soap; and according to the quantity of soap decomposed by a given quantity of water before the remaining soap becomes available as a detergent, so is its relative hardness. The sulphates, chlorides, and nitrates of lime and magnesia give to the water the so-called *permanent* hardness, while the carbonates, which are held in solution by excess of carbonic acid, impart to it its *temporary* hardness, or that which it loses by boiling.

The waters of rivers, from which the greater number of English cities and towns obtain their supplies, contain the above-named mineral constituents in quantities varying according to the composition of the soil over which they flow. In the water of streams which have their sources in the primitive rock formations, as, for instance, the rivers Dee and Don, there is found only from two to eight grains of mineral constituents per gallon. The water of the Trent, which flows through a *selenitic* district, contains about sixty grains of sulphate of lime; while in the water of the Thames, which is derived from, and flows over a chalk formation, there are only about three grains of sulphate, and from eight to ten grains of carbonate of lime per gallon. For the sake of comparison, and in illustration of the above statement, the analyses of the Thames, Trent, Dee, and Don are given:—

	Thames water.	Trent water.	Dee water.	Don water.
Carbonate of lime,	10.80 ..	0.32 ..	0.85 ..	2.23 ..
Sulphate of lime,	3.00 ..	21.55 ..	0.12 ..	0.13 ..
Nitrate of lime,	0.17 ..	— ..	— ..	— ..
Carbonate of magnesia, ..	1.25 ..	5.66 ..	0.36 ..	1.07 ..
Chloride of sodium, ...	1.80 ..	17.63 ..	0.72 ..	1.26 ..
Silica,	0.56 ..	0.72 ..	0.14 ..	0.52 ..
Iron, alumina,	0.27 ..	0.50 ..	0.06 ..	0.27 ..
Phosphate of lime,	trace ..	trace ..	trace ..	trace ..
Organic matter,	2.36 ..	3.68 ..	1.64 ..	3.06 ..
	20.21	50.06	3.89	8.54
Hardness,	14.00	26.50	1.50	3.00

From the preceding analyses it is evident that the proportions of mineral constituents are, in a great measure, dependent upon the nature of the soil over which the water flows. Although the opinions of chemists differ widely regarding the hygienic effects of access of the mineral constituents in water, the Editor is inclined to believe—and this opinion almost universally prevails—that so long as the proportion does not exceed thirty grains per gallon, they are decidedly more beneficial than injurious. The *sense of taste* is perhaps the best guide; and so long as preference is given to a water containing mineral matter to such as are almost entirely free therefrom, it may be assumed that such waters are the best for general purposes.

These remarks apply equally to the waters derived from wells. Indeed, in all the water supplied for man's use there are found the above-mentioned mineral constituents. Are they there for no purpose? Would Nature contaminate water with constituents injurious to health? It has been already mentioned that such waters as contain a certain proportion of mineral constituents, are much more refreshing and agreeable to the taste than those in which they are absent. The remarkable investigations of modern chemists have shown incontestably that a certain proportion of mineral elements in food is absolutely necessary for the due performance of the vital functions. In milk, man's natural food, there are all the elements necessary for the formation of the body—phosphate of lime for the formation of bone; salts of soda to aid in the formation of the gastric juice, and to give fluidity to the blood; casein to form the flesh; and butter to produce fat. In all the cereal grains and in the vegetables which constitute the chief food of gramivorous animals and of man, there are found the *same* mineral constituents which occur in water—*man's natural drink*. Who, then, can deny the value of mineral constituents in the water of wells and rivers? When in very large excess, as in the *shallow* well-waters of London—an exception to the rule—they may, perhaps, tend in some measure to derange the digestive organs of delicate persons, especially of those who have been accustomed to the use of softer water—that is, such as contains less earthy salts—for dietetic purposes; but in most cases in which hard waters are found to disagree, the objectionable effects may, in all probability, be ascribed with greater truth to *organic* impurities than to the actual *mineral* constituents. Having thus briefly alluded to the physiological effects of the mineral constituents of water, it becomes necessary to enter more fully into the nature of the more abnormal *organic* contaminations to which the water of wells and rivers is exposed, since on these is essentially dependent the hygienic character of the water—its fitness for domestic purposes.

NATURE OF THE ORGANIC MATTER CONTAINED IN WATER.—All river and well waters contain more or less of organic matter, which is acknowledged to be a predisposing cause of disease. The separation of these impurities from water is a problem of high scientific interest, and one that has engaged the attention of all the eminent chemists of the day.

The great importance of this subject in a sanitary

point of view renders it necessary to enter into detail regarding it:—

1. The source of organic matter.
2. The nature of the decomposition it undergoes.
3. The means of destroying the organic matter and rendering the water pure and wholesome.

1. *The Source of Organic Matter.*—A river is the natural drain of the country and towns through which it flows, and the organic matter the water contains must necessarily be derived from the three following principal sources:—

From the sewage of towns; from the surface drainage of manured and cultivated lands; and from the decay of the aquatic plants and animals which inhabit the streams.

The sewage of towns consists mainly of the urine and feces of man and animals, the refuse of gas-works and numerous manufactories, which are diluted with the refuse water which has been used for domestic and manufacturing purposes. The Thames, which may be taken as a type of other rivers, before it reaches London drains an area of four thousand square miles, and receives in its course the sewage of towns containing upwards of seven hundred thousand inhabitants. It flows, moreover, through a richly cultivated country, from which it derives vast quantities of organic matter. It is further contaminated with the products resulting from the decomposition of aquatic plants and animals. Hence it is obvious that the water of the Thames, even before it reaches Teddington lock, must be most seriously contaminated with putrefactive organic matter. That much of the organic matter which enters the river is spontaneously decomposed is undoubted, otherwise the river would be little better than a filthy sewer; but that a vast quantity remains in solution in the water as now supplied to the inhabitants of London, is equally a demonstrable fact, as will be seen by the analyses and experiments detailed in the following pages.

Most, and indeed all the companies who take their supply from the Thames, filter the water through sand and shingle previously to pumping it into the mains. By this means most of what exists in it in the form of undissolved or *mechanically suspended particles* is removed, and the water is consequently to some extent improved in appearance. But the greater part of the organic matter is *dissolved* in the water, and is not separated by mere filtration. That much organic matter exists in the present supply is evident from the decided color which the water possesses. This is also the case with the Pike water at present supplied to Liverpool.

If a tall tumbler be filled with any of the water now supplied to London, Liverpool, Manchester, and other towns, and placed on a sheet of white paper, the water will be seen to possess a yellowish or brownish tinge, occasioned by *the organic matter which is held in solution*. The removal of this organic matter, which is doubtless a fertile source of disease in those who daily drink it, is a problem of the highest interest to solve, and one to which MEDLOCK has devoted several years in the hope of its elucidation. Accident in some measure led him to follow out an inquiry into this subject,

which promised to lead to most important results, and the Editor deems the circumstances which suggested this investigation worthy of being recorded; especially as the results arrived at by accurately conducted experiments are not only of high scientific interest in themselves, but, practically applied, are of great hygienic and national importance.

In September, 1856, he was requested by the directors of the Amsterdam Water Company to analyse several samples of water from the city of Amsterdam. Complaints had been made of the water by several of the inhabitants. It possessed a peculiar *fish-like* smell; and although perfectly transparent and colorless, and free from the slightest chalybeate taste, it was found, after standing some time, to deposit a reddish-brown sediment, which coated every vessel in which the water was placed.

The service-pipes being of iron, the deposit was assumed to consist of the sesquioxide, resulting either from the decomposition of a protosalt of iron in solution, or from the attrition of the iron pipes through which the water was conveyed.

It may be observed that Amsterdam is supplied with water from the *Dunes*—sand-hills—in the neighborhood of Haarlem. Trenches, five miles in length, have been dug on the sides of the hills, to intercept the rainfall. The water is conveyed to a large reservoir, whence it flows to the filterbeds at the works, and is there filtered through four feet of filtering medium, consisting of pebbles, shells, and fine sand. After filtration it is pumped up an iron standpipe one hundred and fifty feet high, and conveyed thence by iron mains to Amsterdam, a distance of eighteen miles.

Five samples of the water were sent for analysis—one from the works *before the water came in contact with iron*; the other four from various standpipes in the city.

In the water from the works, before it came into contact with iron, the quantity of iron oxide, alumina, and phosphates amounted to 0.95 grain per gallon. In the analysis of the four other samples, *after passing* through eighteen miles of iron pipes, the quantities were reduced in the several determinations to 0.09, 0.07, and 0.07 grain, and in the fourth sample to an unweighable trace. Thus, instead of taking up an additional quantity of iron oxide from the mains and service-pipes, the water was found actually to have lost nearly the whole of the iron which it previously held in solution; but, notwithstanding the almost entire precipitation of the iron actually in solution in the water which had passed through iron pipes, it formed the objectionable red deposit on standing, while the water from the works, holding in solution nearly half a grain of iron oxide per gallon, formed no such deposit: therefore it was, *a priori*, to be assumed that the red deposit could not consist of oxide of iron, and consequently it appeared necessary to examine this deposit very carefully both chemically and microscopically. The precipitate from ten gallons of water was collected in a porcelain capsule, evaporated to dryness on a water-bath, and heated subsequently in an air-bath to 248° Fahr., until it ceased to lose weight. On ignition, the precipitate *charred* and

was almost entirely consumed, leaving only a minute quantity of ash, consisting of silica, alumina, iron oxide, and carbonates of lime and magnesia.

The small quantity of this deposit at command did not admit of a quantitative analysis. The deposit having been found to consist almost entirely of organic matter, a portion of it, which had been separated from one gallon of water, was examined under the microscope, and was seen to consist of the filaments of dead and decaying algæ, confervæ, and other microscopic plants in various stages of decay, and varying in color, like autumnal leaves, from green through pale-yellow, orange, red, brown, dark-brown to black. Many of the fibres retained a perfectly organized structure, and in some the spores, by which these plants are propagated, were distinctly visible. Amongst these plant remains were numerous silicious tubes, which had probably invested the delicate filaments of the algæ while living.

It appeared highly important to determine the *cause* of the precipitation of the organic matter from the water which had been in contact with the iron pipes; and in the hope of elucidating this interesting question MEDLOCK proceeded to Amsterdam to inspect the source of supply and the works. As anticipated, the Dune canals were found to be actually choked up with aquatic plants, and at the sides and wherever the current was sluggish were large masses of dead algæ floating on the surface. The sand at the bottom, originally very white and pure, was blackened to some depth by decaying vegetal matter, and, when disturbed, numerous bubbles of fetid marsh gas escaped.

The water had the peculiar fish-like smell of the masses of *flab—ulva intestinalis*—floating on the surface. The stones on the sides of the canals, the hurdles placed to keep up the banks, floating pieces of stick, and indeed every *solid* body with which the water came in contact, were coated with a reddish-brown deposit, similar to that which was found to separate from the filtered water in Amsterdam. *This deposit was observed to be particularly abundant near the iron sluice gates.* A pipe from one of the mains in the city was examined at the same time, and found to be coated on the inside with a thick slimy deposit of vegetal remains, which presented under the microscope an appearance exactly similar to that of the deposits above alluded to.

Remembering the important fact established by SCHÖNBEIN, that copper and platinum in a finely divided state have the property of converting ammonia into nitrous acid; and MEDLOCK having demonstrated that *lead* in any form possesses a similar power—it occurred to him that if the same property were possessed by iron, it would throw some light on the separation of the organic matters from waters which are placed in contact with that metal. SCHÖNBEIN, however, states that iron, before it produces a similar oxidizing effect on the ammonia, requires to be heated to redness. But in the course of an extensive series of experiments, it has been found that iron pyrophorus *instantly* transforms ammonia into nitrous acid; and in pursuing the inquiry further, it was found that strips of sheet iron placed in water containing ammonia or

organic matter capable of yielding it, act almost as energetically as the metal in a finely-divided state.

Having proved that metals possess this remarkable power of oxidizing ammonia, and converting it into nitrous acid, and, bearing in mind the extraordinary oxidizing power of this acid, even when present in minute quantities, it appeared to MEDLOCK that he had arrived at a simple and effectual means of depriving water of all organic impurities by thus accelerating a natural process of decay. The facts just mentioned appeared to need a thorough investigation, and the results arrived at will sufficiently prove that he did not, in the first instance, attach too much importance to them. In order to study the action of iron upon the Amsterdam water, he submitted to analysis a quantity of this water which *had never been in contact with iron*, and at the same time he immersed several coils of iron wire in two gallons of the same water. The water in which the iron wire was placed was perfectly bright and free from color, and had nothing visible in mechanical suspension except a few of the siliceous tubes already alluded to. The experiment was made in four open glass bottles. A series of remarkable phenomena were observed. In five minutes a faint white cloud was seen radiating from the coil of wire, and descending in the form of a parachute. In half an hour the cloud had increased in density, and the water became opalescent. In six hours the cloud assumed a brownish color, and there was a brown deposit at the bottom of each of the bottles. The cloud continuing to increase during forty-eight hours, assumed more and more a flocculent character, and a reddish color, exactly like the deposit from the water which had flowed through the iron pipes. The water was now filtered through fine Swedish filter-paper and submitted to analysis, and a portion of the deposit examined under the microscope. The latter consisted of the remains of algæ, each separate flock having a siliceous tube as a nucleus. The remainder of the deposit was burned, and the ash found to consist of oxide of iron, silica, and the carbonate of lime and magnesia.

The following are the analyses of the water before and after being in contact with iron:—

	1.		11.
	Water from the Dune canals.		Same water, having been in contact with iron forty-eight hours.
	Grs per gal.		Grs per gal.
Sulphate of lime,.....	3.70	....	3.68
Chloride of sodium,.....	4.10	....	4.01
Carbonate of lime,.....	5.60	....	3.20
Carbonate of magnesia,.....	3.37	....	1.30
Silica,.....	0.16	....	trace
Iron, alumina, and phosphates,	0.95	....	trace
Matter, volatile on ignition—so called organic matter,.....	2.10	....	trace
	20.58	....	12.19

By these analyses it is seen that the 2.10 grains of organic matter contained in the water *were decomposed or thrown down by contact with iron.* The water, thus purified, no longer had the unpleasant fish-like taste and smell which had marked its previous contamination.

A portion of the water which had been in contact with the iron wire was rendered slightly alkaline by

pure alcoholic potassa, evaporated to dryness, and the residue tested for nitrous acid. The paper became instantly blue from the liberation of a trace of the nitrous acid formed by the oxidation of ammonia, and which had been instrumental in destroying the organic matter.

In the residue of the water which had *not* been in contact with iron and still containing its organic matter, no indication of nitrous acid could be obtained.

The Amsterdam water, the water of the Thames, and indeed that of nearly all other rivers, contain much organic matter, which may be divided into two classes—*nitrogenous* and *non-nitrogenous*. The latter, consisting of carbon, oxygen, and hydrogen, may be represented by the general formula— $n(\text{CHO})$; and, when no longer under the mysterious influence of the vital force, are rapidly resolved into carbonic acid and water. The nitrogenous class being chiefly of animal origin, and composed, in addition to the above-mentioned elements, of nitrogen, sulphur, and phosphorus, may be represented by the general formula— $n(\text{CHONSP})$. Now, when animal matter decays, and when dissolved in water, decomposition proceeds very rapidly; beside carbonic acid and water other and very offensive products are eliminated. As a general rule, the carbon unites with oxygen to form carbonic acid; and with hydrogen, to form marsh gas or carbide of hydrogen; hydrogen and oxygen unite to form water; nitrogen and oxygen with hydrogen to form ammonia; sulphur with hydrogen to form sulphide of hydrogen; phosphorus with hydrogen to form phosphide of hydrogen.

The latter two are exceedingly offensive to the sense of smell, and are, moreover, highly poisonous. Thus in the spontaneous decomposition of the organic matter contained in water there are produced carbonic acid, carbide of hydrogen, ammonia, sulphide of hydrogen, and phosphide of hydrogen. These are the *recognized* compounds; but when it is borne in mind that the gaseous emanations of decomposing animal matters are infinitely more offensive to the sense of smell and injurious to health than any of the gases above mentioned, or of any combination of them, it can only be concluded that the effluvia of decaying organic matter contain other constituents, of which the true character has not yet been determined. Thames water, if allowed to stand in an open vessel for a few days in warm weather, acquires a very offensive odor, arising from the decomposition of the animal and vegetal matter which it holds in solution.

This water, notwithstanding, is considered by maritime authorities to be the very best for the use of ships' companies. On board ship the water is stored in wooden casks, which are placed low down in the hold. During the first week or fortnight, according to the temperature of the atmosphere, the water ferments, evolves a quantity of gas of offensive odor, and deposits a copious brown sediment. The water gradually ceases to smell badly, becomes bright and sparkling, and will then keep fresh and sweet for an indefinite length of time. In other words, it loses by a natural process of decay, the whole of its *putrescent impurities*. In vessels of war, and in most of the large steamers, tanks of iron have been substituted for casks of wood for storing

the water necessary for the use of the passengers and ship's company. In iron tanks Thames water evolves *no offensive gases*, but becomes much purer than when stored in wood, and deposits a more copious brown sediment, which turns red on exposure to the air. The gases produced in the wooden casks are said to be slightly luminous in the dark, and to explode when a lighted candle is incautiously placed near the bung-hole, when the plug is removed. The luminosity is due to phosphide of hydrogen, and the explosive character of the gases to carbide of hydrogen.

As the organic matter was found to be so effectually removed by iron from the Amsterdam water, MEDLOCK instituted a series of experiments upon the water of the Thames. The water operated upon was that supplied to his laboratory by the Grand Junction Company. On placing some of this in contact with iron in glass bottles, precisely similar phenomena were observed as in the case of the Amsterdam water, but the deposit was *black*, and was formed more quickly. The next step in the investigation was to test the water before and after contact with iron for the great destroying agent, NATURE'S SCAVENGER, *nitrous acid*. The residues of six separate gallons of the water were examined for nitrous acid as follows:—Each residue, mixed with half an ounce of water was introduced into a Florence flask, fitted with a cork and long funnel tube. In the neck of each flask was placed a slip of bibulous paper, moistened with starch paste and iodide of potassium. Through each funnel tube was added half an ounce of dilute sulphuric acid, one part strong acid, and nine parts water, to liberate the nitrous acid, if present; but no indication of that gas was found, as the test papers remained perfectly white. Six other gallons of water drawn at the same time, were placed in open bottles, with two ounces of fine iron wire, and left for forty-eight hours. The waters were then filtered from the deposits, evaporated to dryness, and tested for nitrous acid in a manner similar to the preceding, and with the following results:—

- | | |
|----------------|-------------------------------------|
| Experiment 1.— | Paper becomes blue in ten minutes. |
| “ 2.— | Paper becomes blue in five minutes. |
| “ 3.— | Paper becomes blue in four minutes. |

As it appeared probable that the nitrous acid liberated by the sulphuric acid might remain in solution, and in consequence not instantly affect the test-paper, in experiments with the residues of the other three gallons of the water *hot water* was used, and an acid of double strength. In each of these experiments the test-paper became blue in a few seconds.

These results prove beyond a doubt the production of nitrous acid by the action of iron upon the nitrogenous compound contained in the water. The Editor submitted masses of the Piko water to a similar treatment, and found results that confirmed in every respect those attained by MEDLOCK. Why is not this plan of purification adopted by the Water Committee in Liverpool?

EXAMINATION OF THE BROWN DEPOSIT PRODUCED BY IRON.—The brown deposits from three separate gallons of Thames water were collected in porcelain crucibles, and dried at 248° , till they ceased to lose

weight. When thoroughly dried they weighed as follows:—

NO. I.	NO. II.	NO. III.
4·4352 grains.	4·4243 grains.	4·4350 grains.

They were then separately analysed with the following results centesimally:—

	I.	II.	III.
Organic matter,.....	22·92	24·87	23·87
Sesquioxide of iron,....	65·36	63·20	64·39
Carbonate of lime,.....	11·11	11·04	11·20
Carbonate of magnesia, traces	trace	trace	—
Silica,.....	0·59	0·49	0·53
Loss,.....	0·02	0·31	0·01
	100·00	100·00	100·00

In order to arrive at a correct knowledge of the action of iron upon Thames water, MEDLOCK made a series of daily determinations of the mineral residue and organic matter in the water supplied to his laboratory, with the following results:—

	Solid residue. Grs per gallon.	Organic matter. Grs per gallon
Jan. 4th, 1857,.....	20·867	2·248
Jan. 5th, 1857,.....	19·573	1·740
Jan. 6th, 1857,.....	21·159	1·424
Jan. 7th, 1857,.....	20·127	1·401
Jan. 8th, 1857,.....	21·452	3·249
Jan. 9th, 1857,.....	20·374	2·756
Jan. 10th, 1857,.....	20·920	3·062
Average,....	20·638	2·268

At the same time as the water was drawn for the last analysis, he placed three separate gallons in wide-mouthed bottles.

Into the first gallon was put a coil of fine iron wire, weighing half an ounce. After standing two hours the water was filtered, and on being analysed in the usual way, gave—

Solid residue,.....	17·372 grains.
Organic matter,.....	1·232 do.

A second gallon with one ounce of wire for two hours gave—

Solid residue,.....	16·693 grains.
Organic matter,.....	1·170 do.

A third gallon with eight ounces of wire for two hours gave—

Solid residue,.....	13·182 grains.
Organic matter,.....	0·950 do.

In other experiments, too numerous to detail, the water was exposed to the action of a *large surface of iron* from twelve to forty-eight hours; and as a general result it was found that by allowing water to remain in contact with a large surface of iron for about twelve hours, every trace of organic impurity was destroyed, or converted from the soluble to an insoluble condition, in which state it admitted of being effectually removed by ordinary filtration.

After the preceding details on the nature of the organic impurities contained in ordinary well and river water, the offensive gases arising therefrom, and the functions of the numerous microscopic plants and animalcula which are contained in them, it now remains to describe the means that MEDLOCK has adopted for

placing the results of his discoveries at the service of the public.

PRACTICAL APPLICATION OF THE FOREGOING PRINCIPLES.—It has been proved by numerous trials with Thames water, sewage, and water artificially contaminated by mixing therewith sulphide of hydrogen, sulphide of ammonium, and urine, that however impure a water may be, it can be rendered perfectly pure and wholesome to drink by merely allowing it to remain in contact with a large surface of metallic iron for twelve or twenty-four hours, and then filtering through well-washed sand; or, better still, through a mixture of about one part animal charcoal and four parts sand.

The plan above stated is applicable to the purification of the supply of water to towns, as well as to small quantities for domestic and manufacturing purposes. To brewers, dyers, starchmakers, soda water and lemonade manufacturers, *et cetera*, a supply of water free from color and organic impurities is an essential requisite; and the Editor after long and careful study of the numerous processes recommended for purifying water, prefers the one above detailed, as being at once the most simple, easy, and effectual.

The following table exhibits in round numbers the degrees of impurity in water, used for the supply of towns in England, Scotland, *et cetera*, each degree being equal to one grain per gallon—

Distilled water,.....	0°
Loch Katrine,.....	2·0
Dec—Aberdeen,.....	4·0
Tay—Perth,.....	5·5
Dumfries,.....	7·0
Gorbals,.....	8·0
Leven,.....	8·5
Clyde,.....	9·5
Tyne—Newcastle,.....	11·0
Tweed—Coldstream,.....	11·5
Seine—Paris,.....	12·0
Liverpool well, purest,.....	13·0
Glasgow “ “.....	15·0
Kilmarnock,.....	15·0
Thames—1854,.....	15·5
“ —1851,.....	21·0
Glasgow well, most impure,.....	96·0
Liverpool well, “.....	417·0

Disease occasioned by the Organic Impurities of Water.—Dr. HASSALL remarks—In proof that water highly charged with decomposing organic matter frequently gives rise to severe and fatal diseases, often of an epidemic character, one is able to produce abundance of evidence. To occasion these effects, no doubt the organic matters, animal or vegetal, resolve themselves into carbide, sulphide, and phosphide of hydrogen, cyanides, *et cetera*, as well as other lethal products, and these disarrange the whole functions of the body. To enter more minutely into this part of the subject would be out of place in a technological work.

Disease occasioned by the Metallic Impurities in Water.—The Editor has known most serious illnesses to arise from water containing lead. Many hard as well as soft waters act injuriously upon lead, consequently, as a general rule, water should never be stored in cisterns of this metal. Why use lead when one can have slate cisterns and enamelled iron pipes? A

gentleman and his family residing in the neighborhood of Liverpool were constantly ill, but whenever they left home they recovered. The water was supposed to be the cause, and was tested from time to time, and pronounced good. The amount of lead was small, and had been overlooked—as is very often the case with inexpert analysts. On examination of several gallons of the water—it was a remarkably soft water—lead was detected. The Editor recommended slate cisterns and enamelled iron pipes, and from that day to this all the ill effects of the water disappeared.

Microscopic examination of Water.—Most well and river waters, when allowed to stand in an open vessel for several days, especially in warm weather, deposit a sediment more or less copious, in which may occasionally be discovered, by means of a microscope, a vast number of the lower forms of animal and vegetal life, which have been made the subject of special study by several able microscopists, and especially by Drs. HASSALL and LANKESTER. Much misapprehension, however, appears to prevail regarding the extent to which these lower forms of organic life occur in water. In works treating on this subject, it is usual to group a large number of these objects together in a circular drawing, which convey the impression, and are generally understood to represent the animalcula contained in a single drop of water. Nothing, however, can be more erroneous, and nothing more calculated to convey false notions regarding the character of the water supplied to the public.

It appears to be a law of nature, that wherever the conditions of life exist, there life will manifest itself in forms suited to the circumstances. If a portion of earth be brought up from the deepest mine, and exposed for some time to the combined influence of heat, light, and moisture, various forms of vegetal and animal life will appear, even if the soil be entirely excluded from contact with the surrounding atmosphere. In the water of rivers containing animal and vegetal matter in a state of decay, are presented all the conditions of life; and hence the numberless forms of the lower organisations which are met with. That these are injurious to health, no one can venture to affirm; but their presence may form, to some extent, an index of the quantity of putrefactive organic matter which may be present. In cases where it is necessary to examine a water microscopically, the following is the plan recommended by the Editor:—

About a quart of the water to be examined should be placed in a conical glass vessel, very narrow at the bottom, in shape something like a tall champagne glass, and covered over with paper. After remaining at rest some hours, a slight deposit will generally be observed at the bottom; and in this deposit will often be seen numerous small animalcula moving about with wonderful rapidity; these have been named by naturalists *Cyclops quadricornis*. They are particularly abundant during the summer in river waters containing much organic matter. Other crustacea are also abundant, amongst which may be mentioned various species of *Daphnia*, which, by their number, often give a marked yellow color to water. Of radiate animals, the hydra and other forms of zoophytes are frequently

present. The fresh water sponge—*Spongia fluviatilis*—frequently occurs in great abundance. Numerous lower forms of the vegetal kingdom often abound in river waters, especially in those of shallow streams. These belong chiefly to families *Conservaceæ*, *Dismidiæ*, *Diatomaceæ*, and *Fungi*. Many of these lower organisms are beautiful objects under the microscope, and well worthy of the attention of all lovers of nature. Space will not allow of any detailed description of the almost numberless species found in water; they have been only briefly alluded to with the view of pointing out the fact, that when they occur in water used for dietetic purposes, they must be regarded as a proof of the presence of dead and decaying organic matter, and must not be looked upon as the only kind of contamination of the water. Their function appears to be to destroy the numerous organic matters which are present. To examine well the deposit formed in the conical glass, the clear water should be siphoned off, and a portion of the deposit placed in the field of the microscope—a quarter-inch glass is perhaps the best for such observations.

Dr. HASSALL examined several specimens of water, both upwards and downwards in the course of the river Thames from London, and they brought to light the singular and important fact that Thames water, from Brentford in one direction to Woolwich in an opposite,

Fig. 613.



swarms with living productions, principally of the genus *Paramcium*, and of one species of this genus *P. chrysalis* of EHRENBURG.

The engraving exhibits the principal animal and vegetal productions contained in the Thames water at Richmond, drawn with the camera lucida, and magnified two hundred and twenty diameters.

The subjoined cut exhibits the more remarkable vegetal and animal productions found in the water of the Thames at Waterloo Bridge.

Fig. 614.

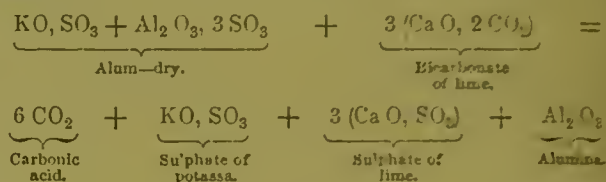


Color of Water.—In rivers the impurity of water is frequently visible to the eye. It is often of a red color, as it flows through rocks of red marl which contain much oxide of iron in their composition. It descends milky from the glaciers of Iceland and the slopes of the Andes, because of the white earth it holds in suspension. It is often grey or brown in the muddiest English rivers. It is always brown when it issues from boggy lakes, or runs across a peaty country, as at Rivington Pike. It is occasionally black to the eye when the amount of vegetal matter is excessive, as in the Rio Negro of South America; and it is green in the geysers of Iceland, in the Swiss lakes, among the islands of the South Sea, and around Great Britain and Ireland. Only in clear and deep water, like those of the Bay of Naples, and in parts of the Pacific, where minute objects may be seen on the bottom some hundreds of feet down, is the real blue color natural to water in large masses distinctly perceptible. This is the deep blue which is seen in the *grotto azzura* of the island of Capri, in the Bay of Naples, and in the deep indigo waters of some parts of the Mediterranean and Adriatic seas.—*Johnston.*

THE ADDITION OF CHEMICAL AGENTS TO WATER.—This head includes several proposed methods of purifying water, which consist in the addition of certain chemical agents to this liquid, by which its composition is altered.

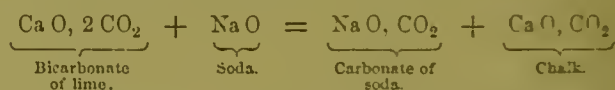
Addition of Alum.—In England, as well as in France, a popular method of clearing muddy water is

to add a few grains of powdered alum to it; two or three grains are usually sufficient for a quart of water. This process is called *alunage de l'eau*; and ARAGO states, that when practised on the Seine water, it causes the mud to agglomerate in long thick strata, which are very quickly deposited. The theory of the process appears to be this:—The alum decomposes the bicarbonate of lime, and gives rise to the formation of sulphate of lime, which, with sulphate of potassa, remains in solution, while carbonic acid is evolved, and hydrate of alumina being precipitated in a flocculent form, carries with it various mechanical impurities.

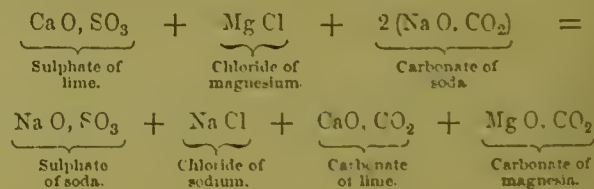


This method, then, is a kind of mechanico-chemical one. It clears the water, but at the same time alters its chemical composition, and by converting bicarbonate into sulphate of lime, augments the hardness of the water.

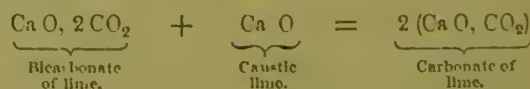
Addition of Caustic or Carbonated Alkalies.—Caustic alkalies, added to water holding in solution bicarbonate of lime, saturate the excess of carbonic acid, throw down carbonate of lime, and leave an alkaline carbonate in solution. If soda be the alkali used, the results will be as follows:—



If an alkaline carbonate be employed, all the earthy salts—calcareous and magnesian sulphates, chlorides, bicarbonates, and carbonates of the earths—are precipitated, while alkaline sulphates, chlorides, and bicarbonates which do not communicate hardness to water, are left in solution. If carbonate of soda be employed, its reaction on sulphate of lime and chloride of magnesium will be as follows:—



Addition of Lime.—A few years ago, Professor CLARK of Aberdeen took out a patent for the purification of water. His process consists in the addition of caustic lime to water, by which the bicarbonate of lime held in solution is decomposed; the caustic lime saturates the excess of carbonic acid, and forms carbonate of lime, which is precipitated.

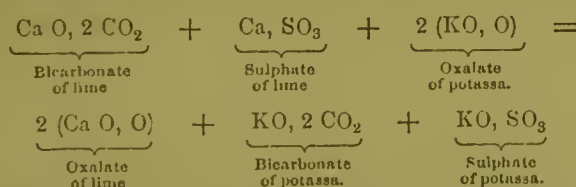


The Editor believes the process of CLARK to be *virtually impracticable on the large scale*, while its efficacy is but slight.

It must be remembered that this mode affects the bicarbonate of lime, not the more troublesome earthy salts, such as the sulphates and chlorides, on which the hardness of spring waters mainly depends. The difficulty of mixing lime and water, in definite proportions, on the large scale, must be obvious to every one. If too much be employed, the companies would supply their customers with *lime-water*! If too little, the bicarbonate of lime would not be completely destroyed, and the process would be a failure. Altogether, the difficulties of carrying out the process will ever prevent its adoption on a large scale.

Addition of Oxalate of Potassa.—MR. HORSLEY of Cheltenham, some years ago, took out a patent for a new method of preventing incrustations in boilers, and also for depurating, filtering, and otherwise rendering water more fit for drinkable and other purposes. When sea-water is taken for generating steam, he purifies it by employing oxalate of potassa and ammonio-phosphate of soda; and the proportions he uses for the water of the British Channel are about two drachms of oxalate of potassa to about two ounces of the ammonio-phosphate of soda for every gallon. When his object is to februate and soften hard water, he employs such substances as are capable of decomposing the calcareous salts, such as calcined or caustic baryta, or baryta water, phosphate of soda, silicate of potassa, oxalic acid, or the oxalates, and caustic strontia, or strontia water; but he gives the preference to oxalate of potassa. He first ascertains the degree of hardness of the water, and then adds the requisite quantity of oxalate of potassa, by which an oxalate of lime is precipitated; and there remains in solution, instead of the lime thus displaced, a carbonate, sulphate of potassa, or chloride of potassium, as the case may be, and the water is purified and fit for use.

The following equation explains the reaction of oxalate of potassa; the salt is assumed to be neutral on bicarbonate and sulphate of lime:—

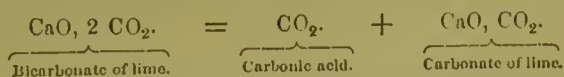


HORSLEY's patent process does that which CLARK's fails to do: it decomposes all the earthy salts on which the hardness of water usually and mainly depends. But it is open to still greater objections than those that have been raised to the other method. Besides being, like CLARK's, process virtually impracticable, it would prove very expensive, and as regards the metropolitan river-waters, it is quite unnecessary. Moreover, the idea of *physicking* or *doctoring* water, by the addition to it of a poisonous agent, would, if even no other objection existed to this scheme, be quite fatal to it. For though, in the hands of competent persons like Mr. HORSLEY, no possible injury could arise from its use, yet the public would always have some suspicion of water thus treated; and, as a celebrated English engineer observed to ARAGO, water, *like Caesar's wife, should be above suspicion*, which the Rivington Pike

water supplied to Liverpool is not. Liverpool was formerly supplied with spring water from the red sandstone, beautifully cool and refreshing, and free from organic matter. Now the inhabitants are forced by a stubborn water committee to drink a mixture of the *rock* and *surface* water—how the people suffer it is to the Editor a mystery—the latter certainly *blasting its wholesome brother*. The small town of Flint, North Wales, has infinitely better water than is supplied to any of the principal towns of England.

Purification and Filtration of Water.—JOHNSTON says truly, that the water used by a nation or country is an important matter in a well-considered and long-adjusted diet. It by no means follows in all cases, perhaps not even in the majority, that the *purest* water—see *Distilled Water*—is the best for the health of a given family, or for the population of a given district. The bright, sparkling, hard waters which gush out in frequent springs from the chalk and other limestone rocks are relished to drink, not merely because they are grateful to the eye, but because there is something exhilarating in the excess of carbonic acid they contain and give off as they pass through the warm mouth and throat, and because the lime they hold in solution neutralizes or counteracts acid matters in the stomach, and thus acts as a grateful medicine to the system.

On entering upon the purification and filtration of water, it may be stated as an axiom that *the best filter is no substitute for bad water*; still, as various towns throughout the kingdom are supplied with bad water, that is, water containing chemical and mechanical impurities, the Editor deems it necessary to explain to the reader how to remove these wholly or in part, so as to *better* the water. The depuration of water is greatly aided by repose, by which various suspended or mechanical impurities are allowed to subside gradually, and from these the supernatant fluid is drawn or siphoned off. Tanks, cisterns, and reservoirs become therefore important depurating agents. The purification of water by subsidence and decantation is the simplest of all methods of februation; but unfortunately it is a very slow one. It is stated that the water of the Garonne, taken when the river is swollen, does not regain its natural limpidity after a fortnight of perfect rest. The larger particles, of course, quickly deposit, but the finer ones precipitate very tardily. During the time that deposition is occurring, the water is exposed to the air, and consequently undergoes a chemical metamorphosis. The bicarbonate of lime which is dissolved in it parts with a portion of its carbonic acid, and carbonate of lime precipitates:—



In this way the atmosphere assists in softening those waters, which owe the whole or a portion of their hardness to the above calcareous salt. The atmosphere, however, is a source of contamination as well as of purification, and it is on this account that the Editor always condemns the use of *surface* water for dietetic purposes. EHRENBURG states that, exclusive of inorganic substances, he has detected three hundred and twenty species of organic forms in the dust of the

winds. It is obvious, therefore, that waters which are chemically very pure, must become contaminated by exposure in deposit reservoirs.

What are the best methods of purifying water on a large scale?

The water, says TOMLINSON, used for culinary, domestic, and industrial purposes, is exclusively derived from the rain which falls upon the earth, whether the immediate source of supply be the cistern, the well, the spring, or the river. Rain-water is usually so pure, that the action of the most delicate chemical tests is required to detect any foreign substance in it; so that, if cisterns were formed of proper materials, and the rain fell directly into them in sufficient quantity, no better water could be desired. But as the exposed surface of cisterns is too small to collect rain-water in any quantity, it is usual to discharge into them, by means of gutters and shoots, the water which falls upon the roofs of houses; and, as these are covered with dust, insects, and other impurities collected during dry weather, the rain-water of cisterns is thus contaminated in various ways. In some places the rain-water, collected on the surfaces of extensive roofs and flats, is made to pass through a bed of porous materials on its way to the cistern, and thus the solid impurities are strained and separated before the water is used by the public. Such is the case with the large cistern of the ducal palace at Venice.

Wells may be compared with cisterns; but the channels which discharge rain-water into them are not formed of masonry, brick, or metal, but of the rocks which exist immediately beneath the surface. These rocks may be porous, or may abound in minute fissures, through which the rain-water, sinking through the soil, finds a passage; and being divided into innumerable liquid threads, it dissolves and carries along with it a portion of whatever soluble matter it may encounter. Hence, the water obtained from wells is not rain-water, properly so called; it is usually as clear and limpid, but it contains nearly always certain substances in solution, which vary according as the geological structure of the country differs. The same remark applies to springs: their water is rain-water, which, after having traversed strata of greater or less thickness, is sent up to the surface by the pressure of the water in the neighboring hills or other elevations. The nature and proportion of the impregnation to which spring-water is subjected, depend also on the extent of its transit and the kind of rock traversed. The action of rain-water upon certain kinds of rock leads to the production of mineral springs; and if the water descends to a certain depth in the earth, its temperature will be so much raised by the internal heat, that on reappearing at the surface, it will be as a thermal spring.

In filtering on a large scale, for the supply of a city, for example, the cost and durability of the filter are important considerations. On the great scale of Nature, the rocks which filter the water, as it falls upon the surface of the soil, constitute a vast permanent filter, the durability of which arises from the great extent of superficial or subterranean surface concerned. It might at first view appear to be easy to imitate this natural operation, and pass the muddy water of a river through

the porous rock or sand which forms its bank: but this is often an expensive proceeding, on account of want of permanence of an artificial structure so contrived. Toulonse is supplied with water from the Gironde in this way, and it has cost upwards of forty thousand pounds at various times for supplying a city of only fifty thousand inhabitants. The cause of failure in this and other instances arises from the fact already noticed, that when water percolates sand, it deposits its solid impurities to a certain depth between the interstices of the filtering medium, rendering it necessary from time to time to renew the sand. This is illustrated by some experiments conducted by Mr. WICKSTEED. A sand filter which yielded at the rate of ten the first week, yielded nine the second week, six the third week, and only two the fourth week; so that a large natural filter—as this description of filter is called—may go on for some years, yielding a good supply of water, and then gradually diminish it until it ceases altogether. Hence the construction of these so-called natural filters requires much caution on the part of the engineer; and it will always be difficult, if not impossible, to calculate before hand the amount of water which a natural filter proposed to be erected will yield.

A second system of filtration on a large scale consists in the formation of extensive beds of sand of great thickness, resting on beds of gravel, *et cetera*. At intervals of time, from ten to fourteen days, the water is run off; and the filth which had accumulated during filtration is scraped off with a certain thickness of the sand of the filtering bed. Once or twice a year the whole of the sand removed is replaced. This method is costly, and not altogether satisfactory.

Of all the permeable substances used for filtration, animal charcoal possesses in the highest degree the combined mechanical and chemical influence. In addition to its power, in common with other filtering media, of removing suspended or mechanical impurities, it also abstracts from the liquid which percolates it, various *dissolved* bodies, and thus effects a metamorphosis in the chemical composition of the fluid which traverses it. These important properties of animal charcoal have oftentimes led to its use as a filtering medium for water; and hence it is introduced into many of the ordinary domestic water filters. But its deodorizing and decoloring power is soon lost; and, in order to enable it to reacquire its original efficacy, it requires to be re-formed.

There can be no doubt that of all known permeable bodies, the only ones which present all the requisites of filtering media for water on a large scale, are sand and gravel. They are cheap, allow the rapid passage of water through them, and, when *they have been previously well washed*, communicate no taint to the waters which traverse them. Their employment must have been suggested to man by the observation of the numerous limpid springs which are seen in arenaceous districts.

Their action, however, is chiefly *if not entirely* mechanical. They possess little or none of that power of effecting chemical changes on the liquids filtering through them, which animal charcoal possesses in so pre-eminent a degree. Yet, unless several distri-

guished writers have grossly deceived themselves, sand is not entirely devoid of this chemical influence. WAGENMANN, for example, found that when vinegar was filtered through pure quartz sand, the first portion of liquid that percolated was deprived of almost *all its acid*; and the vinegar did not pass through unchanged until the sand had become well charged with acid. The same authority also states that potato-brandy diluted with water, and filtered through quartz-sand, yields at first pure water, then a mixture of water and alcohol deprived of its fusel-oil; and, lastly, the original mixture unaltered. BERZELIUS filtered a saline solution through a long tube filled with sand, and found that it ran out more or less completely deprived of salt. MATTEUCCI repeated BERZELIUS' experiment, and confirmed his statement. He filled a tube about twenty-six feet long with sand, and filtered a saline solution through it; and he found that the density of the liquid introduced by the upper aperture of the tube was to that of the liquid escaping from the lower end, as 1.00 to 0.91. But he observed that this difference of density was not always maintained; for, after a certain time, the saline solution becomes as dense at its exit from, as at its entrance into the tube, proving that the decomposition of the saline solution takes place in the first action of contact between it and the particles of sand. But a still more remarkable result, the inverse of the one just stated, was obtained by the last-mentioned chemist, with a solution of carbonate of soda. He filled a tube nearly ten feet long with sand, and filtered a solution of carbonate of soda through it; and he found that the density of the liquid at its entrance was to that at its exit as 1.000 to 1.005. In this case, then, the sand had deprived the solution of part of its water, and had thereby increased the gravity of the liquid which percolated. Assuming, however, the accuracy of all these reported observations, it cannot be doubted that, *in a practical point of view*, the efficacy of sand, as a filtering medium, depends *on its mechanical, not on its chemical influence*.

Domestic Filters.—In coming now to notice small filters for domestic purposes, such a multitude of inventions and contrivances start up to view that, as TOMLINSON says, how to choose and where to begin is difficult. There are certain classes of subjects, says the same authority, on which the genius of inventors seems to run riot. *Filters* form one of these, and *fire-escapes* another. In either class examples are as numerous as the attempts to solve the problem of perpetual motion, or to square the circle. Almost every kind of porous substance has been enlisted into the service of filters. The animal, vegetal, and the mineral kingdoms have each contributed. Charcoal—animal and vegetal—sponge, flannel, cotton, straw, hemp, saw-dust, wood shavings, branches and leaves, various kinds of porous stone, sand, pounded glass, zinc and iron filings, are a few only of the materials that have been recommended or used; and the methods of employing them are as various and as dissimilar as the substances themselves. The Editor considers the best filter for home use to be that of FORSTER of Liverpool, which he employs in his own house. The water percolates a fine porous stone, which removes all mechanical impurities, and

imparts a freshness to the water, which is not the case when sponge, charcoal, and other substances are the filtering media. It is, as TOMLINSON states, remarkable that very few filters were exhibited in the foreign department of the Great Exhibition. France sent three—two of stone and one of charcoal. An ingenious form of filter was exhibited by the Wenham Lake Ice Company, which consisted of a siphon, the extremity of the short limb of which is furnished with a box containing the filter, so that on inserting this into a cistern or cask holding water, and applying suction at the extremity of the longer limb, a stream of filtered water can be obtained, which may be arrested or drawn at will by shutting or opening the tap, as seen in the figure. In the laboratory, unsized paper is almost exclusively employed as a filtering medium. Other substances, such as flannel, tow, sand, pulverized glass, may occasionally be used.

An arrangement is also made for retaining the liquor in the filter at the same height, until the whole of the fluid to be percolated is expended. To insure this, the menstruum to be passed through is held in a flask inverted, the neck of which, as the reader will perceive by the wood-cut, dips into the liquor already contained in the funnel. As the liquor descends, and the neck of the flask becomes uncovered, a bubble or two of air enters; more liquor exudes, until the neck becomes again immersed, and all communication with the air is again cut off.

VESSELS FOR CONTAINING WATER.—Lead and other metals are very useful to store water in. The Editor is very glad to find, however, that the clean, inexpensive, and beautiful material, slate, is coming into use for cisterns, instead of lead, which is a dangerous metal to have in contact with a liquid of such daily and universal consumption.

DISTILLED WATER.—Certain technical and analytical purposes demand that the water employed by the operator or analyst be perfectly pure. To insure this, distillation is resorted to, by which operation the foreign matters held in suspension or solution are separated. Dr. NORMANDY remarks, that the distillation should be arrested when the salts begin to precipitate; for if the process were continued, part of these saline matters might suffer decomposition, and thus contaminate the distillate. The annexed table from NORMANDY shows the characteristics of pure water. It must not become turbid, or produce a precipitate with any of the subjoined reagents:—

Baryta water—If a precipitate or opaqueness appear, carbonic acid is present.
 Chloride of barium—Shows sulphates.
 Nitrate of silver—Indicates chlorides.
 Oxalate of ammonia—Evidences lime salts.
 Sulphide of hydrogen, solution made slightly acid—Antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth, cadmium.
 Sulphide of ammonium, solution alkalinized by ammonia—Nickel, cobalt, manganese, iron, zinc, alumina, chromium.
 Chloride of mercury, chloride of gold, sulphate of zinc—Prove organic matter.

Pure distilled water, evaporated on a piece of platinum foil, *should leave no residue*. As a drink it is insipid, and is not recommended except in some cases of calculi.

The following table, embracing the composition of some principal river and well waters, will prove interesting to the reader:—

GRAINS IN THE IMPERIAL GALLON.

	RIVER.								WELL.	
	Clyde, Glasgow. Penny.	Leven Penny	8 Ine. Dewille.	Rhine Dewille.	Garonne Dewille.	Loire. Dewille.	Rhone Dewille.	Donne Dewille.	Artois, at Paris.	Isère.
Carbonate of lime,.....	2.52	.50	11.609	9.511	4.524	3.374	5.334	13.397	12.958	16.133
Sulphate of lime,.....	.26	.52	1.886	1.030	—	—	—	—	11.450	—
Chloride of calcium,.....	—	—	—	—	—	—	—	—	—	—
Carbonate of magnesia,...	.72	—	.189	.350	.238	.427	3.430	.161	.575	—
Sulphate of magnesia,...	—	—	trace	—	—	—	—	—	—	—
Chloride of magnesium,...	.40	.66	—	—	—	—	—	.035	1.163	—
Sulphate of soda,.....	1.94	.39	—	.945	.371	.238	.519	.357	.378	.18
Carbonate of soda,.....	—	—	—	—	.455	1.023	—	—	—	.147
Chloride of sodium,.....	.54	.73	.862	.140	.224	.336	.119	.161	2.657	.224
Sulphate of potassa,.....	1.94	.39	.350	—	.533	—	—	—	1.410	—
Nitrate of potassa,.....	—	—	—	2.660	—	—	.280	.257	—	.18
Nitrate of soda,.....	—	—	.659	—	—	—	.315	.273	—	—
Nitrate of magnesia,.....	—	—	.364	—	—	—	—	—	3.958	—
Phosphates—earthy,.....	.31	.18	—	—	—	—	.333	—	—	—
Alumina,.....	.28	.32	.035	.175	—	.498	—	.147	.371	.7
Oxide of iron,.....	trace	—	.175	.406	.217	.385	—	.210	—	—
Silicic acid,.....	.28	.32	1.711	3.423	2.813	2.848	1.669	1.114	2.146	1.005
Organic matter,.....	.89	.45	—	—	—	—	—	—	—	—
	7.86	3.75	17.840	16.247	9.585	9.437	9.082	16.142	37.126	18.283

Physiological Effects.—Water is an essential part of the blood and of the living tissues. It is from this liquid that the tissues derive their properties of extensibility and flexibility. It gives fluidity to the blood, and enables the transportation of organic particles from one part of the body to another to be effected. Lastly, it contributes to most of the transformations which occur within the body. Considered dietetically, aqueous drinks serve several important purposes in the animal economy: they repair the loss of the watery part of the blood, caused by evaporation and the action of the secreting and exhaling organs, and thereby assist the stomach in the act of digestion. If, however, they are swallowed in excessive quantity, they may impede digestion by diluting the gastric juice. It is not improbable that water acts as a real nutritive agent, that is, assists in the formation of the solid parts of the body. As an agent for the communication or abstraction of heat to or from the body, water has been before noticed. Furthermore, the influence of atmospheric humidity modifies the character of climates.

Water moderately warm, and which neither cools nor heats the body, acts locally as an emollient, softening and relaxing the various tissues to which it is applied. When swallowed, it allays thirst, becomes absorbed, mixes with and thereby attenuates the blood, and promotes exhalation and secretion, especially of the aqueous fluids. Administered in large quantities, it excites vomiting. The continued excessive employment of water has an enfeebling effect on the system, both by the relaxing influence on the alimentary canal, and by the excessive secretion which it gives rise to. Injected into the veins in moderate quantities, tepid water has no injurious effects; it quickens the pulse and respiration, and increases secretion and exhalation. Large quantities check absorption, and cause difficulty of breathing and an apoplectic

condition. Thrown with force into the carotid artery, it kills by its mechanical effects on the brain.

Besides the dietical and thermotic purposes for which water is employed in medicine, it serves as a diluent, humectant, emollient, evacuant, and, in pharmacy, as a solvent. Water, or bland aqueous fluids, are employed in some cases of poisoning. They serve to dilute the acrid and irritant poisons, the intensity of the action of which on the stomach they lower. Moreover, the presence of aqueous fluids favors the expulsion of substances by vomiting. In preternatural dryness and rigidity of parts—for example, of mucous surfaces, the skin, wounds, and ulcers—water and mild aqueous fluids are useful moisteners and emollients. The copious use of water augments the quantity of fluid thrown out of the system by the cutaneous and pulmonary surfaces, and by the kidneys. If the object be to promote diaphoresis, external warmth should be conjoined with the internal use of diluents; whereas, when one wishes to excite the renal vessels, the skin should be kept cool. In inflammatory affections of the urinary passages, the free employment of aqueous fluids is advised, with the view of diluting the urine, and thereby of rendering it less acrid and irritating. What is called water-dressing may be regarded as a modified and improved form of poultice. It consists in the application of two or three layers of soft lint dipped in water, and applied to inflamed parts, wounds, and ulcers, the whole being covered with oil silk or Indian rubber, which should project beyond the margin of the lint to retain the moisture, and prevent evaporation. Dr. MACARTNEY considers it to operate differently to a poultice; unlike the latter, he says, it prevents or diminishes the secretion of pus, checks the formation of exuberant granulations, and removes all pain. Moreover, the water is not liable to become sour like a poultice, and does not injure the sound part. Water

is frequently employed in pharmacy for extracting the active principles of various medicinal agents.—*Pereira*.

MINERAL AND OTHER WATERS.—*GLOVER* justly remarks that few subjects connected with medicine are more interesting to the general reader than that of mineral waters. The circumstances attending their administration, the natural mode of their production, the scenery in which they are often placed, and the associations frequently surrounding them, combine to give them, as remedies, an interest exceeding that of ordinary medicinal agents. Hygiene and medicine, in the narrow acceptation of the terms, join hand in hand at the salubrious fountain. Spas have been exalted, and are still exalted by interested parties, as panacean cures for all diseases; others unworthily decried; source has been pitted against source, and pump against pump; and battles fought between biassed spa-doctors, which only tended to raise doubts in the opinions of thinking men.

To enter largely into the subject of natural and artificial mineral waters would be quite out of place in a book of this description, and it would be incompatible with the assigned limits to give more than a general insight into their nature, character, composition, and manufacture. The great *furor* for saline and other springs is daily abating; a very striking proof of this being evidenced at Cheltenham, to which thousands used to rush yearly to partake of its waters, whereas now it is almost entirely deserted. The same, no doubt, will soon be the case with other places, and artificial will, in many cases, supply the place of natural waters. Is not more due to the diet, change of scene and air, than to the virtues said to be possessed by certain springs? What miraculous cures are stated to have been produced by the water of Holywell, Flintshire, North Wales; and yet analysis reveals *nothing* particular in this spring to impart to it medicinal properties, as illustrated by the annexed tabulated results of Mr. JAMES BARRATT, pupil of the Editor—

Temperature,..... 52°
Specific gravity,..... 1.0015

	Grains. Per Imperial gallon.
Carbonate of iron,.....	traces
“ lime,.....	13.685
“ magnesia,.....	2.688
“ soda,.....	1.432
Chloride of calcium,.....	3.094
“ potassium,.....	traces
“ sodium,.....	0.821
Silicic acid,.....	2.737
Sulphate of lime,.....	5.202
“ magnesia,.....	traces

Total,..... 29.659

Direct determination of fixed constituents, 30.450

Free carbonic acid, 10.338 grains, = 21.874 cubic inches.

This famous spring is the first in Great Britain; it never freezes, and scarcely varies in the quantity of water it emits, drought or wet weather, flinging out *twenty-one tons a minute*.

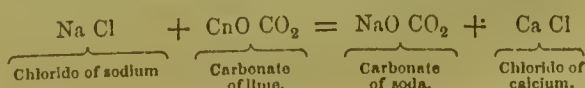
PEREIRA remarks—Mineral waters were known to mankind in the most remote periods of antiquity, and were employed medicinally both externally and internally. *HOMER* speaks of tepid and frigid springs. The *Æsclepiadæ*, or followers of *ÆSCULAPIUS*, accord-

ing to *SPRENGEL*, erected their temples in the vicinity of mineral and thermal waters. *HIPPOCRATES* mentions mineral waters, although he does not prescribe them when speaking of particular diseases. Their medicinal properties are spoken of by *PLINY*.

The principal source of saline waters is the rain, snow, hail, dew, percolating a certain portion of the soil, and dissolving various matters in their passage, so as to reappear on the surface at the bottom of declivities as spring-water; or when procured by sinking pits or wells—well-water. But springs are sometimes observed, continues *PEREIRA*, under circumstances which are inconsistent with the supposition of their atmospheric origin. The boiling springs, says *GAIRDNER*, which emerge on the verge of perpetual snows at an altitude of thirteen thousand feet above the level of the sea, as in the Himalayas, cannot be derived from the air.

Mineral waters, of course, procure their particular and distinctive properties or qualities from the strata through which they flow. Those of the primitive formation are almost all thermal, generally possessing a high temperature, while those of the older secondary formations are generally cooler. The hot or thermal waters are those possessing a degree of heat more or less raised above the mean of the latitude or elevation at which they are found, and the changes of which, if any, observe no regular periods coincident with the revolutions of the seasons. Three causes, says *PEREIRA*, have been assigned as the source of the temperature of mineral waters, namely, volcanic action, now in existence; volcanic, now extinguished, but the effects of which still remain; and a central cause of heat, which increases in descending from the surface to the interior of the earth. The *Geysers*, or boiling springs of Iceland, are evidently the result of volcanic action.

PEREIRA proceeds—The origin of the saline and other constituents of mineral waters is another interesting topic of inquiry connected with the natural history of mineral springs. As water, in its passage through the different strata of the globe, must come in contact with various substances which are soluble in it, one refers certain constituents of mineral waters to solution and lixiviation merely, as chloride of sodium, carbonates of lime and magnesia, oxides and bromides of sodium and magnesia, iron, silicic acid, *et cetera*. Chemical action must, in some cases, be the source of other constituents. Sulphide of hydrogen is most likely the result of the action of water on some metallic sulphide, especially iron pyrites; sulphurous or sulphuric acid from the oxidation and combustion of sulphur, free or combined. In acidulous or carbonated waters the carbonic acid probably arises from the decomposition of chalk either by heat or sulphuric acid. The disintegration of chlorides of sodium or ammonium would eliminate hydrochloric acid, while carbonate of soda, found so largely in the native lakes of Egypt, might, as *BERTHOLLET* supposes, be proved by the action of chloride of sodium or carbonate of lime; thus—



GAIRDNER states that the different orifices of the Karlsbad Sprudel discharge annually about thirteen thousand tons of carbonate of soda and twenty thousand tons of sulphate of soda, in a crystallized state; and further adds, that a very simple calculation is sufficient to prove that the Donnersberg alone, the highest of the Bohemian Mittelgebirge, a cone of clinkstone two thousand five hundred feet in elevation, eviscerates soda sufficient to supply the Karlsbad waters for more than thirty thousand years.

The Editor agrees with PEREIRA that the best classification to adopt is that of grouping mineral waters into four classes, *videlicet*, chalybeate, sulphurous, acidulous, and saline.

CHALYBEATE OR FERRUGINOUS WATERS.—These terms are applicable to those waters, the active principle of which is *iron* in considerable quantity. These waters possess a styptic taste, and when they contain the protoxide of the metal, yield, with ferrocyanide of potassium, a *white* or bluish-white precipitate; and if the sesquioxide be present, they give a *blue* precipitate with ferrocyanide of potassium, and become *red* with

the alkaline sulphocyanide. The carbonated chalybeates are of two kinds, those containing the carbonate of iron, associated with much carbonic acid, which renders them acidulous and effervescent. The Pyram, Trinkquelle or drinking spring, Schwalbach Spa, and Poulhon, are of this nature.

The noneffervescent ones are Oddy's saline chalybeate at Harrowgate, the Islington Spa near London, and the waters of Tunbridge Wells. These are also sulphated chalybeates, but they are not of so much importance.

SULPHUROUS OR HEPATIC WATERS.—The most celebrated of these waters are—in England, those of Harrowgate, the appended analyses by Dr. A. W. HOFFMANN being given; Scotland—Moffat and Rothesay; of the Continent—Enghien, Barèges, Aix, near Geneva. Aix-la-Chapelle, and Baden. They have the disagreeable smell of rotten eggs, and give, with salts of lead, bismuth, copper, *et cetera*, black precipitates.

Subjoined are analyses by Dr. HOFFMANN of several of the most important saline chalybeates at Harrowgate:—

GRAINS OF SALINE CONSTITUENTS IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Temperature,	48.2°	46.4°	42.8°	41.9°	44.6°	48.2°
Specific gravity,	1.01113	1.01045	1.00314	1.00515	1.0026	1.0118
Ammonia,	trace	trace	trace	trace	trace	trace
Bromide of sodium,	trace	—	trace	trace	trace	trace
Carbonate of iron,	trace	trace	trace	1.060	trace	trace
“ lime,	12.365	24.182	20.457	25.560	19.794	6.300
“ magnesia,	—	—	3.251	5.797	—	—
“ manganese,	trace	trace	trace	trace	trace	trace
“ potassa,	—	—	—	—	—	12.237
“ soda,	—	—	—	—	—	5.153
Chloride of calcium,	81.735	61.910	—	—	—	—
“ magnesium,	55.693	54.667	17.140	11.595	0.336	—
“ potassium,	64.701	5.750	3.975	10.751	24.970	—
“ sodium,	866.180	803.093	232.413	369.014	220.650	121.738
Fluoride of calcium,	trace	trace	trace	trace	—	faint trace
Iodide of sodium,	trace	—	trace	trace	trace	trace
Organic matter,	trace	trace	trace	1.327	trace	1.740
Silica,	0.246	1.840	0.165	0.535	1.49	1.753
Sulphate of lime,	0.182	0.594	12.104	51.660	1.215	0.870
Sulphide of sodium,	15.479	14.414	3.398	7.155	0.301	1.711
Total,	1096.581	966.450	292.903	484.454	279.046	157.562

GASES DISSOLVED BY THE WATERS AND EXPELLED BY EBULLITION IN VACUO.

Composition in one hundred volumes.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	61.06	70.62	62.50	31.79	44.07	49.78
Carbide of hydrogen,	16.17	2.71	3.99	0.52	22.80	27.71
Nitrogen,	8.08	24.21	33.51	65.88	25.31	22.51
Oxygen,	—	2.46	—	—	7.82	—
Sulphide of hydrogen,	14.69	—	—	1.81	—	trace
Total,	100.00	100.00	100.00	100.00	100.00	100.00

CUBIC INCHES OF THE GASES IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	22.03	14.01	14.28	9.54	10.20	9.26
Carbide of hydrogen,	5.84	0.53	0.90	0.15	5.28	5.15
Nitrogen,	2.91	4.82	7.67	19.78	5.87	4.21
Oxygen,	—	0.48	—	—	1.81	—
Sulphide of hydrogen,	5.31	—	—	0.54	—	trace
Total,	36.09	19.84	22.85	30.01	23.16	18.62

COMPOSITION OF THE GASES, IN ONE HUNDRED VOLUMES, RISING FROM THE WATER IN BUBBLES.

	Old sulphur well	Hospital strong sulphur spring.
Carbonic acid,.....	3.28	0.09
Carbide of hydrogen,.....	40.00	—
Nitrogen,.....	56.72	99.91
Oxygen,.....	—	—
Sulphide of hydrogen,.....	trace	trace
Total,	100.00	100.00

The sulphide of hydrogen exists in the above waters, partly free and partly combined. Only a portion can be expelled by ebullition. The amount of the sulphide of hydrogen in the waters varies, which may be partly due to influences affecting the strata through which the waters ascend; to a great extent, however, they must be ascribed to the action of the air.

The general operation of these waters, says PEREIRA, is stimulant. They are adapted for chronic complaints, and are supposed to possess a specific power over the cutaneous and uterine systems, and are said to be beneficial in chronic rheumatism and gout. As previously remarked, would not an iron salt, judiciously administered, act just as well in the above-mentioned diseases?

ACIDULOUS OR CARBONATED WATERS.—The name here implies waters charged with carbonic acid. Most waters contain a few cubic inches of carbonic acid in the gallon, but the acidulous will eviscerate from thirty to two hundred cubic inches. It is stated by ALIBERT that the waters of Saint Nectaire hold four hundred cubic inches in one hundred of the water.

Carbonate or bicarbonate is contained in waters of this kind, and, when this is the case they are called *acidulo-alkaline*. The Selters, Altwasser, Salzbrunn, Reinerz, and Pyrmont acidulous waters are of this description. Protocarbonate of iron is sometimes present in them, classifying them under *acidulous carbonated chalybeates*. The spring at Ilkeston, near Nottingham, is the only water of the above class in Great Britain.

Acidulous waters are cooling, refreshing, and exhilarating, and oftentimes relieve nausea. The acidulo-alkaline waters are useful in the lithic acid diathesis, in gout and rheumatism, *et cetera*.

SALINE WATERS, according to PEREIRA, may be divided into five kinds:—

Purging Saline Waters.—Sulphates of soda or magnesia are the active ingredients of these waters: some owe their efficacy to sulphate of magnesia, others to sulphate of soda.

Bitter Purging Waters, Bitter Waters, Bitter-Salt Waters.—Sulphate of magnesia predominates in these waters. Epsom and Scarborough in England, and Seidlitz, Saidehütz, and Püllna on the Continent, are of this kind. Some thermal springs, as those of Acqua del Pozzeto, near Pisa, contain sulphate of magnesia.

Glauber Salt Waters.—Some writers give this name to those waters holding sulphate of soda in solution. Some of these are warm, and on this account are called the *warm alkaline glauher salt waters*. To this division belong the famous springs of Carlsbad,

now so much resorted to for good—or evil! Further on analyses are given of the Carlsbad water, and of several others of the leading and well-known Continental springs. Some of this class of waters are devoid of alkaline properties, but contain, besides sulphate of soda, various earthy and alkaline salts. They are the *earthy glauher salt waters*. To this division belong the deserted springs of Cheltenham, and those of Leamington and Spital.

In large doses the waters of this kind are mild cathartics. PEREIRA says they are useful in diseased liver, dropsical diseases, *et cetera*.

Salt or Brine Waters.—The characteristic ingredient of these springs is chloride of sodium. Iodine or bromine, or both, have been found in some of them, and these most likely add to their medicinal effects. The small quantity of iodine recently found in the water of St. Ann's Well at Great Malvern, Worcestershire, by the Editor, is doubtless the active ingredient in that water.

The Krenznach and Salzhausen springs in Germany are among the brine springs, and in England the principal ones are at Middlewich and Nantwich in Cheshire, Shirleywich in Staffordshire, and Droitwich in Worcestershire.

Taken in large quantities, saline or brine springs are emetic and purgative. They have been principally celebrated in glandular swellings. The water of Baden Baden contains a large quantity of chloride of sodium.

Analysis of the water of Baden Baden by the Editor:—

	Imperial gallon. Grains.
Alumina,.....	trace
Carbonate of iron,.....	1.356
“ lime,.....	14.184
Chloride of calcium,.....	11.040
“ potassium,.....	13.720
“ sodium,.....	132.644
Organic matter,.....	trace
Phosphate of lime,.....	trace
Silicic acid,.....	2.947
Sulphate of magnesia,....	5.236
	181.127
Specific gravity.....	1.00284
Carbonic acid.....	4.5 cubic inches.
Sulphide of hydrogen.....	trace.

Calcareous Waters.—These saline mineral waters, the leading constituent of which is either the sulphate or carbonate of lime, belong to this order.

The Buxton, Bath, and Bristol thermal waters, come under the same category. Annexed is an analysis of the Buxton water just completed by the Editor; it differs materially from the one made by his friend PLAYFAIR some time ago, except in the amount of gases:—

	Grains in the Imperial gallon.
Carbonate of lime,.....	8.541
Carbonate of magnesia,	3.741
Carbonate of protoxide of iron,.....	0.082
Sulphate of lime,.....	0.230
Chloride of calcium,.....	1.227
Chloride of magnesium,.....	0.463
Chloride of sodium,.....	2.405
Chloride of potassium,.....	0.260
Silica,.....	1.014
Nitric acid,.....	trace
Organic matter,.....	0.341
Fluoride of calcium,.....	} trace
Phosphate of lime,.....	
Total per gallon,.....	18.434
Free carbonic acid,.....	3.5 cubic inches.
Nitrogen,.....	504 "

Calcareous waters are stimulant, alterative, and constipatory. Externally they are said to be beneficial in the cure of rhenmatism, gout, chlorosis, chronic skin diseases, *et cetera*.

The quantity of nitrogen gas accompanying this water has been previously alluded to. Dr. ROBERTSON, in treating of the physical characters of the Buxton waters, ascribes their brilliancy when drawn to the quantity of gas *held in solution*. Of course, this must be fallacious, for very little gas is *held in solution* or *dissolved*. As GLOVER remarks, what occurs in the baths, where a quantity of the nitrogen has been forced along by the current of water, three hundred gallons per minute, furnishes no indication of the amount of *gas in solution*. The great use of the Buxton water is, of course, externally, but upon what its effects mainly depend *still remains unexplained*.

Mr. J. ARMITAGE PEARSON, the eminent consulting surgeon of Buxton, has informed the Editor that he does not look upon the *nitrogen* in any water to be an effective element; and although one sees the gas constantly gurgling forth in strong streams, still Mr. PEARSON agrees with the Editor, that being an *insoluble* gas, it is not absorbed into the system; and even *supposing that it could be absorbed*, it could not exert any beneficial result. All water is a diuretic, more or less. Mr. PEARSON places very little value on the Buxton waters *per se*; but administered with a certain and most valuable medicine—an alkaloid—which he has prescribed, he has effected several wonderful cures. The lime salts in the water no doubt exert a beneficial influence.

To divert the reader's attention a little, the following anecdote with regard to how waters of one kind or another become celebrated, is given by the writer of *Bubbles from the Brumms of Nassau*, with regard to the discovery of the far-famed waters of Sclaugenbad. It is characteristic of the supposed origin of many similar watering-places, and as such it may amuse, if it does not much edify, the reader:—In the history of the little Duchy of Nassau, says that graceful writer, the discovery of the spring forms a story full of innocence and simplicity. Once upon a time, there was a heifer with which everything in nature seemed to disagree. The more she ate, the thinner she got. The more her mother licked it, the thicker and more staring was her coat. Not a fly in the forest would bite her. Never was she seen to chew the cud; but, hide-bound and

melancholy, her hips seemed to be actually protruding through her skin. What was the matter with her, no one knew; what could cure her, no one could divine: in short, neglected by her master and her species, she was, as the faculty would term it, *given over*. In a few weeks, however, she suddenly reappeared among the herd with ribs covered with fat, eyes like a deer, skin as sleek as a mole, breath smelling sweetly of milk, saliva hanging in ringlets from her jaw. Every day seemed to re-establish her health, and the phenomenon was so striking, that the herdman, having watched her, discovered that regularly every morning she wound her way in secret into the forest, until she reached an unknown spring of water, from which, having refreshed herself, she quietly returned into the valley. A young Nassau lady showed symptoms similar to those of the heifer, and the herdman recommended the water, which cured her!

GLOVER says justly in his very readable work on mineral waters, that there is a certain mystery connected with the origin and mode of operation of some of them, which no doubt with many is attractive, just as in the extraordinary doctrines of HAHNEMANN and others. Many of these waters, and especially the thermal ones—Buxton, *et cetera*—produce effects in general estimation far beyond what can be accounted for, either by their chemical composition and the power of their *known* ingredients, or by their temperature as shown by the thermometer, in comparison with those of ordinary water baths.

ALKALINE WATERS.—Carbonate and bicarbonate of soda are the characteristic ingredients in such mineral waters. The thermal springs of Teplitz and Ems come under this class, also the Vichy waters, which have long been noted for the cure of stone and gravel: but of late years they have been the subject of discussion among French physicians as to their efficacy in these disorders.

Among the mineral waters in this country which contain carbonate of soda are those of Ilkeston in Derbyshire, near Nottingham, and Malvern in Worcestershire, an analysis of the latter being appended. These waters have only recently been minutely analyzed in the Editor's laboratory:—

	St. Ann's Well, Great Malvern, Editor.	Holy Well, Malvern Wells, Barratt.
	In the imperial gallon.	
Alumina,.....	—	traces
Carbonate of iron,.....	0.0331	0.22470
“ lime,.....	0.4310	1.02480
“ magnesia,...	0.4111	1.48400
“ soda,.....	0.2844	0.93310
Chloride of magnesium,...	0.1448	—
“ sodium,.....	0.8768	0.94570
Iodide of potassium,.....	0.00021	—
“ sodium,.....	—	0.00029
Silicic acid,.....	0.2057	0.13250
Sulphate of lime,.....	1.1521	1.65690
“ soda,.....	0.4382	0.09360
Organic matter,.....	—	traces
	3.9772	6.55859
Specific gravity,.....	1.0013	1.0012
Carbonic acid in cubic inches,.....	1.382	6.722
Temperature,.....	48°	46°

The above waters issue from the rock at the rate of

about three gallons a minute, and they have been renowned as highly advantageous as an external application to indurated scrofulous tumors, ulcers, and many eruptive diseases, owing to the trace of iodine, as well as efficacious and beneficial when taken internally, for acidity, dyspepsia, *et cetera*—if so, why not take the active ingredient *per se at home*?

Dr. BOOKER thus apostrophizes the Holy Well—

Ever could I stray
Beside thy stream thou purest spring that flows;
Climb each bold eminence, and daily find
Some object new for wonder—ever gaze
On the wide scene around me, and regale,
When thirst demands, or pleasing taste invites,
At thy clear rill that sparkles at my foot,
And think it luxury.

Chemically it is not the purest spring that flows, that of St. Ann being much purer. *Poetically*, however, it may be.

Silicious Waters.—Most mineral waters contain traces of silicie acid, but some hold it in such quantity that the term *silicious* is applied to them. In the boiling springs of Geyser and Reikum in Iceland it amounts to nearly the half of the solid constituents. The action of such water—of course the silica is united to an alkali—will be similar to those of the soda or potassa waters. Annexed are analyses of several of the most important mineral waters on the Continent:—

	Sprudel Carlsbad.	Ems. Kesselbrunnen.	Selters.	Gastoin.	Teplitz, Hauptquelle.	Wildbad	Kissingen.	Kreuznach Karlsbader- brunnen.	Pyrmont Trinkquelle
	Temp. 165° sp. gr. 1·00417.	Temp. 116° sp. gr. 1·0034.	Temp. 60·5° sp. gr. 1·0036.	Temp. 95° sp. gr.	Temp. 119° sp. gr. 1·00065.	Temp. 90·5° sp. gr.	Temp. 62° sp. gr.	Temp. 61·5° sp. gr. 1·000.	Temp. 57° sp. gr.
Carbonate of baryta,.....	—	0·03	—	—	—	—	—	—	—
“ iron,.....	0·27	0·26	1·54	0·22	0·37	0·20	6·80	3·64	4·90
“ lithia,.....	—	—	—	—	1·82	—	—	—	—
“ lime,.....	23·70	11·40	18·67	3·97	3·25	3·40	35·50	6·13	59·88
“ manganese,...	0·06	0·03	—	trace	0·80	—	tracc	6·54	0·48
“ magnesia,...	13·69	7·88	15·95	0·35	0·53	0·70	25·00	4·73	3·23
“ soda,.....	96·95	107·50	58·55	6·90	26·84	5·30	8·20	—	—
“ strontia,....	0·07	0·10	trace	trace	0·19	—	tracc	—	—
Sulphate of lime,.....	—	—	—	—	—	—	25·00	—	72·21
“ lithia,.....	—	—	—	—	—	—	—	—	0·09
“ magnesia,...	—	—	—	—	—	—	—	—	26·97
“ potassa,.....	—	5·40	—	0·55	4·34	0·20	—	—	0·42
“ soda,.....	198·69	—	2·48	14·95	—	4·00	20·00	—	21·45
“ strontia,....	—	—	—	—	—	—	—	—	0·20
Phosphate of alumina,....	0·02	0·018	—	—	0·22	—	—	—	0·14
“ lime,.....	0·01	—	—	trace	—	—	—	—	—
“ soda,.....	—	—	2·81	—	trace	—	1·70	—	—
Chloride of ammonium,...	—	—	—	—	—	—	0·50	—	—
“ calcium,....	—	—	—	—	—	—	—	25·61	—
“ lithium,....	—	—	—	—	—	—	—	0·56	—
“ magnesium,...	—	—	—	—	—	—	68·50	6·79	11·26
“ potassium,...	—	0·45	3·58	—	1·04	—	9·10	4·07	—
“ sodium,.....	79·75	76·34	162·85	3·40	4·33	18·20	620·50	596·65	—
Iodide of magnesium,....	—	—	—	—	—	—	trace	—	—
“ sodium,.....	—	—	—	—	0·56	—	—	0·44	—
Bromide of magnesium,...	—	—	—	—	—	—	7·00	66·02	—
Fluoride of calcium,.....	0·24	0·019	—	—	—	—	—	—	—
“ sodium,.....	—	—	—	—	1·30	—	—	—	—
Alumina,.....	—	—	—	0·50	—	—	1·80	4·32	—
Silicic acid,.....	5·77	4·14	2·89	2·02	3·12	3·90	22·50	0·31	4·96
Glairine,.....	—	—	—	trace	0·90	—	5·30	14·72	—
	419·22	213·567	269·32	25·96	49·61	35·90	857·40	760·53	206·19

SEA WATER—*Aqua Marina.*—The waters of the ocean and inland seas are comprised under this head. It is rather a remarkable fact that the Dead Sea differs greatly in its constitution from sea-water, and might, as stated by PEREIRA, to whose excellent work the Editor is indebted for most of the preceding valuable information, be ranked amongst mineral waters.

According to the analysis of MARCET, the water of the Dead Sea contains 24·6 per cent. of fixed matter, and possesses an extraordinary density, 1·211—

	Centesimally represented.
Chloride of sodium,.....	10·360
“ calcium,.....	3·920
“ magnesium,.....	10·246
Sulphate of lime,.....	0·054
Water,.....	75·420
	100·000

The amount of saline matters varies considerably in

different seas, as instanced by the following results from PFAFF. The solid constituents are in ten thousand parts of the water of each:—

Mediterranean.....	410
English channel.....	380
German ocean {	
At the Island of Föhr	340
“ “ of Norderney.....	342
In the Frith of Forth.....	312
At Ritzbüttel.....	312
Baltic Sea. {	
At Apenrade in Sleswick.....	216
At Kiel in Holstein	200
At Doberan in Mecklenberg....	168
At Travemünde.....	167
At Zoppot in Mecklenberg	76
At Carlsham.....	66

To assume that the average quantity of solid matter is three and a half per cent., and the density about 1·0274 will be very near the mark.

Annexed are the analyses of SCHWEITZER and LAURENS, of two samples of sea-water:—

	English Channel. Schweitzer.	Mediterranean. Laurens
Chloride of sodium.....	27.05948 ..	27.22
Chloride of potassium.....	0.76552 ..	0.01
Chloride of magnesium.....	3.66658 ..	6.14
Bromide of magnesium.....	0.02919 ..	—
Sulphate of magnesia.....	2.23578 ..	7.02
Sulphate of lime.....	1.40662 ..	0.15
Carbonate of lime.....	0.03301 ..	} 0.20
Carbonate of magnesia.....	— ..	
Water.....	964.74372 ..	959.26
	1000.00000	1000.00

SCHWEITZER also detected iodine and ammonia, and BALARD found iodine in the Mediterranean; and no doubt it contains bromine and other constituents. In fact MALAGUTI detected *silver* in sea-water.

To render such water fit for drinking, it is evident that the greater part of these saline constituents must be removed; and, as TOMLINSON remarks, it has long been a desideratum to enable ships' crews to employ sea-water for different culinary purposes, with the view of removing the necessity of carrying large supplies of fresh water. Almost innumerable are the contrivances invented to meet this end, and, according to the above-cited authority, the most effective is GRANT'S, by which the cooking of victuals and the purifying of water are carried on synchronously. The apparatus is called *the distilling and cooking galley*. The galley contains the fires and vessels necessary for cooking. During the time when the fires are ignited, a portion of the heat is applied to the external part of vessels containing sea-water; the water boils, and steam distils over, leaving, of course, the salts in the still. The steam condenses in a worm, and is nearly pure water, which, of course, is vapid; but the taste may be improved by access to open air and agitation. Where steam-power is used, GRANT'S apparatus affords a ready and effective means of separating fresh-water from salt. PEREIRA says that CLARK'S patent improved pyrohydropneumatic apparatus for easily converting sea-water into fresh is a convenient form of still adapted for sea service. Congelation separates fresh from sea-water. In freezing the pure water only congeals, not the saline ingredients; hence the ice of the polar seas yields fresh water.

Physiological Effects and Uses.—Sea-water taken into the stomach excites thirst, nauseates, and in large doses occasions vomiting and purging. The repeated use of it in moderate doses has been found of service on account of its alterative and resolvent operation in scrofulous affections, especially glandular enlargements and mesenteric diseases. Its topical action is more stimulant than ordinary water. It is used as an embrocation in chronic diseases of the joints. Baths of it are not so exhausting as those of common water. It is a popular opinion, perhaps well founded, that patients are less likely to catch cold after the use of salt than of fresh water.—*Pereira*.

ARTIFICIAL AND AERATED WATERS.—About forty years ago, when the fabrication of mineral and spa waters commenced, a very violent opposition arose with regard to them, especially from the members of the faculty. They were said to be devoid of all the good qualities of the natural ones—to be minus a certain *conditio sine qua non*, in the shape of a *spiritus rectus*, or vital force,

which imparted the medicinal qualities. The Editor lived to see such statements reversed. Chemistry, the great revealer of hidden treasure, has demonstrated to a certainty what the constituents of the natural water are; and thus one is now enabled to produce artificial waters quite equal, if not superior to the natural ones. At the Brighton pump-room many artificial waters are prepared imitative of those of Carlsbad, Pyrmont, Vichy, Kreuznach, Ems, Seltzer, and many others, too numerous to detail. MESSRS. ELLIS of Ruthin prepare a beautiful imitation of the Seltzer water which, on being analysed by the Editor, yielded exactly the same constituents as the far-famed Bohemian spring. The artificial is certainly more palatable than the natural water, owing probably to the freshness of the carbonic acid infused into it by the admirable apparatus of TYLER, which will be explained further on. To dwell particularly on artificial waters would be tedious and uninteresting to the reader; it is sufficient to state that in their manufacture the salts, in the same proportion as contained in the natural spring, are dissolved in as pure a water as possible, and are then more or less charged with carbonic acid or other gases.

It was PRIESTLEY who, in 1772, proposed to impregnate water direct with carbonic acid, and in 1774 prescriptions for the artificial production of Selters and Pyrmont waters, founded on an accurate analysis of the same, were published by BERGMANN.

Some years ago LIEBIG analysed the Friedrichshaller water, and it is now prepared in large quantities exactly with the salts, *et cetera*, and in the same proportion as given in his results; and if one may judge by the success the imitation has met with, the artificial has almost entirely supplanted the natural beverage. The Editor may here remark, that it is to a certain extent immaterial whether one dissolves carbonate of magnesia, carbonate of lime, sulphate of lime, chloride of sodium, sulphate of soda, *et cetera*, or, on the other hand, chloride of magnesium, chloride of calcium, carbonate of soda, and sulphate of soda, if care be taken that the proportion of the respective bases and acids are strictly in accordance with the figures given by analysis; since they will, in all probability, combine in the same manner as they are associated in the natural spring. The rapid increase and spread of the manufacture of artificial waters, is the best proof that physicians find the medical and therapeutic effects of them are *identical* with those of the natural ones, whilst their *identity* in a physical and chemical point of view can hardly be questioned.

Now that the chemist is able to distinguish the ingredients actually efficacious in a water, a much more active mixture than the native spring can be prepared. To show the extent to which the manufacture of aerated waters has advanced, Messrs. ELLIS and SOX, the celebrated manufacturers of soda and other carbonated beverages, inform the Editor, that at Ruthin alone, North Wales, they send out yearly *many thousand gross of effervescing beverages*. So that with other factories at London, Malvern, Liverpool, Manchester, Glasgow, *et cetera*, the trade has within the last few years become an enormous one.

Soda-Water.—This is certainly the principal aerated

water manufactured. How many thousands or millions of bottles of it are drunk annually either alone or mixed with sirups, wines, or spirits? The materials for soda water are carbonate of soda and tartaric acid.

It is a well-known fact that a large portion of the soda water in general use is simply carbonated water, without the alkali, and as such, is a safe and agreeable beverage; but the physician, or the invalid, or any one who seeks therapeutic and corrective influences of the water, will be greatly disappointed in the use of these fluids, as they are inert, and for such purposes worse than useless. It is difficult to find a person who is not subject to occasional annoyance from acidity. To such an individual a glass of soda-water has been found to impart immediate relief. The carbonic acid appears to produce a peculiar sedative action upon the irritated mucous lining of the stomach, and the alkali neutralizes the excess of acid, and restores the organ to a condition of comfort which few but those who have suffered from the annoyance of heartburn can appreciate. Dr. BENCE JONES, in a treatise upon gout, strongly recommends the use of soda or potassa waters, but laments that the waters so-called in commerce are not alkaline at all; and numerous physicians of eminence have expressed the same complaint.

Some time ago the Editor was greatly pleased in inspecting the admirably conducted establishment of ELLIS at Ruthin, North Wales. Everything was so nice and clean; and, as for the water employed from a deep and splendid well upon the premises, it might be said to be absolutely pure; and it is on this account that he considers the soda, potassa, and other beverages prepared in these works superior to any other in the market. Messrs. SCHWEPPE and others, no doubt, manufacture equally well; but they do not start with *as pure a fluid*. The quantity of soda or potassa in each bottle at Ruthin is twenty-five grains of the bicarbonate of either alkali; and the carbonic acid is equal to about two hundred and fifty or sixty cubic inches, showing how well the gas is compressed. The water from the well only holds *two grains* of solid matter in solution, and *has not a trace of organic matter*; hence it is not liable to alterate or decompose, if kept for any length of time. The apparatus will now be described; and for the following, the Editor is again, as in several instances, indebted to TOMLINSON's excellent Cyclo-pedia.

An elegant little apparatus has been brought into use within the last few years, patented by M. MATHIEU, as an improvement upon an earlier invention. It is calculated for the preparation of aerated beverages in private houses rather than for sale, since it can yield but a small quantity at a time. There are two oval glass vessels—the larger one placed vertically over the smaller. There is a passage of communication from the one to the other, and in this passage there is a tap for drawing off the aerated liquid. The upper or larger glass is filled with water by removing the cover; and the lower or smaller glass is supplied with the powders. These powders are, as in other cases, of different kinds, according to the sort of beverage to be produced. A small pipe descends from nearly the top of the upper to nearly the bottom

of the lower vessel; a little water descends through this pipe, mixes with the powder, and produces gases; and these gases ascend to the water in the upper vessel. Of course, such gases only as are soluble in water are generated. The gas chiefly used is carbonic acid, of which water will absorb its own bulk, and by pressure can be made to take up another volume. As the gas accumulates in the upper vessel, the pressure increases, and the water is thus enabled to take up its additional supply. The two vessels are generally surrounded with a netting of wire or cane for security. In the simpler forms of the apparatus, nothing further presents itself; but in M. MATHIEU's improvement there is a refrigerating contrivance. The upper vessel is surrounded by an external shell and sheath, so as to leave an intervening space; and into this may be introduced either ice, or cold water, or freezing mixture.

GAILLARD and DUBOIS' gazogene, or aerated water apparatus, is a much more complicated contrivance. It contains three distinct chambers or vessels—one for the water to be aerated, one for the effervescing powders, and one to contain a small quantity of water which is to act upon the powders. It is necessary to separate all three vessels when the apparatus is to be prepared for use; and this is one cause of its complexity. When all three have been properly supplied, the finger is pressed upon a stud or button at its top. This pressure opens a valve which allows the water in the small upper vessel to descend into the one containing the powders. The gas, thus generated, can only escape from the powder-vessel by descending a small tube which dips into the larger one; and the water with which this larger vessel is nearly filled becomes impregnated with the gas. A second finger-stud governs the valve of a small pipe, which enables the aerated water to flow from the apparatus, which is elegant in construction, but has not the elegance of simplicity.

Mr. MASTER's aerating machine is similar in principle to MATHIEU's, though differing in details. The powders are placed in the lower part, and the water in the upper; a little water descends to the powders, and the generating gas ascends. A stud, acted upon by the thumb, draws off the beverage when required.

MESSRS. TYLER, HAYWARD and Company's patent double soda-water machine is adapted for bottles, and can make three hundred dozen *per diem*. There are two distinct machines in one frame, which can be worked together or separately. It consists of a condenser divided into two by a partition inside. Each half has an agitator, worked by a wheel. There are two condensing pumps, with regulating taps for admitting aerated water. The pumps are worked by a beam. The beam, by its reciprocating motion, causes the plungers beneath the pumps to ascend and descend in their barrels, forcing at each successive stroke the gas and water together into the condenser. About ten minutes are required to get the charge up, and the bottling then goes on uninterruptedly.

MESSRS. TYLER and Son have invented single and double soda-water machines of ingenious construction. Mr. W. COX of Manchester has patented an apparatus

in which the impregnating gas may be sustained at a pressure sufficient to cause its absorption by the water without the aid of force-pumps. BAKEWELL'S apparatus is another contrivance, applicable to the preparation not only of cooling drinks, but of effervescing draughts also, whether tonic, aperient, diuretic, anti-acid, or peptic. In short, every aerating apparatus may be said to comprise these two parts—one to produce a gas, and one to mix it with plain water, or water containing carbonates of soda, potassa, magnesia, *et cetera*, or orangeade, lemonade, gingerade, and the like.

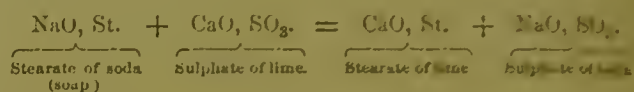
ANALYSIS OF WATERS.—Method of Testing for and Determining Nitrous and Nitric Acids.—Almost all river waters, and especially the shallow well waters of towns, contain variable quantities of nitrous and nitric acids generally in combination with lime, as nitrite and nitrate of that base. Their constituents have hitherto been generally overlooked by analysts, but on their presence and quantity the chemist may form a more correct idea as to the contamination of the water by organic matter than by any other means. The Editor, therefore, attaches the greatest importance to the determination of these constituents, especially when the water is selected for domestic use.

It has been previously stated that ammonia is one of the principal products of the decomposition of animal matter. This ammonia very speedily becomes oxidized and converted into nitrous acid— NO_2 —which, by longer exposure, is further oxidised into nitric acid— NO_3 . The above-mentioned acids depend for their origin on the presence of organic matter capable of yielding ammonia, and the solvent action of waters upon lead, is almost entirely due to these acids.

Method of Determining the Hardness of Water.—The so-called *hardness* of a water is dependent, as already stated, upon the presence of a certain proportion of the salts of lime and magnesia, which possess the property of decomposing an equivalent quantity of soap, and rendering it useless as a detergent. These salts are bicarbonates of lime and magnesia, and the sulphates of the same basis. The former impart to water its *temporary*, and the latter its *permanent* hardness. The two bicarbonates are decomposed by boiling; the insoluble monocarbonates being deposited, and, mixed with small quantities of the other mineral constituents, form the incrustations which are frequently observed on kettles and boilers in which hard water is employed. In order to determine the temporary and permanent hardness of water, the following method is adopted:—

Into a six ounce stoppered bottle put one thousand grains of water; agitate briskly, and suck out the air by means of a piece of glass tube. This is necessary in order to remove the free carbonic acid, which might interfere with the soap test. Fill the graduated burette with soap test solution, add one measure, and agitate briskly. If no lather is produced, add more, and shake again. Continue adding the soap-test till a permanent lather is produced. Even in moderately hard water a white opalescence appears immediately on adding a few drops of the test, and a white curdy mass will be seen to collect on the surface. Pure soap, such as is used in

making the test solution, is a stearate or palmitate of soda, which is readily soluble in pure water; but when it is added to a water containing salts of lime and magnesia, the soluble soda-soap is decomposed, and an insoluble soap of lime and magnesia produced. The decomposition is represented in the following equation:—



A similar decomposition takes place with soluble salts of magnesia, and hence, when hard waters are used for washing, not a particle of soap will act as a detergent until the whole of the lime and magnesia is removed.

In accurate analysis it is important to make a double determination of the hardness—one before the water is boiled, and another after a portion has been boiled for about six hours. The degree of hardness after boiling represents the hardness due to sulphates and chloride of the alkaline earth metals, while the difference between the hardness obtained after and before ebullition indicates that which is due to the carbonates of these metals. For example, if a water has a hardness of fourteen degrees before boiling, and of four degrees after, the water is then said to have a temporary hardness of ten degrees, and a permanent hardness of four degrees.

That the determination of the hardness of water is important cannot be denied, since it furnishes a certain guide to the proper association of the acids and bases when one comes to arrange the results of a complete analysis. But until chemists are agreed upon the character of a type-water, its true value cannot be properly appreciated.

Determination of the free Carbonic Acid in Water.—Water which has been allowed to stand for some hours in an open vessel becomes insipid and mawkish to the taste, or in popular language, it is flat. This is owing to the escape of carbonic acid, which occurs in many spring and well waters. Hence, in giving a correct opinion of the value of a water for dietetic purposes, it is sometimes necessary to determine the number of cubic inches of free carbonic acid in a given measure of the water. This is an operation which ought to be performed at the source, and is best done in the following manner:—A well-stoppered glass bottle holding a gallon is required for the purpose. Put into it two fluid ounces of strong ammonia, and two fluid ounces of a saturated solution of chloride of calcium. If both materials are pure, the mixture will remain perfectly bright. After observing that no milkiness is produced, depress the bottle into the stream or well, and fill it gradually, taking great care not to dip the neck entirely beneath the surface, but only partially, so as to allow space for the air to pass out, while the water is flowing in. This precaution is essentially necessary, since, if the water were to be agitated by the air escaping from the bottle, much of the free carbonic acid would be expelled by the agitation so occasioned, and hence erroneous results would be obtained.

After carefully filling the bottle with the water, it is

to be stoppered and left for three or four days. After that time, the whole of the carbonic acid will have been precipitated in the form of carbonate of lime. This is to be filtered off, dried, and weighed. From the total weight of the precipitate is calculated the quantity of carbonic acid according to the following formula—

$$50 : 22 :: \text{the weight of carbonate of lime} : x$$

The value of x will give the quantity of carbonic acid contained in the water.

Some, however, of this carbonic acid is in combination with lime and magnesia, and it is therefore necessary to determine the quantity, in order to ascertain how much exists in a free state. This requires a separate operation. A gallon of the water is introduced into a large glass flask, and boiled for six hours. The diminution in bulk occasioned by evaporation is made up with pure distilled water. The precipitate produced by boiling is collected on a filter, and the portion adhering to the bottom of the flask is dissolved by a little dilute hydrochloric acid. The precipitate on the filter is dissolved, and the two solutions mixed together. The solution will contain traces of silica, iron, alumina, and phosphate, which may be disregarded; its chief components are carbonate of lime and carbonate of magnesia, which being separately determined, their weight is to be deducted from the weight of the precipitate obtained from the bottle in which the ammonia and chloride of calcium had been used. From the difference may be calculated the quantity of carbonic acid per gallon. One grain by weight measures as nearly as possible two cubic inches. Therefore, if the difference in the weights of the two precipitates amount to a weight of carbonate of lime containing twenty grains of carbonic acid, the water will be proved to contain forty cubic inches of that gas in a free state per gallon.

Determination of the Alkalinity of Water.—By the alkalinity of water is understood the quantity of potassa or soda which may be present in combination with carbonic acid. For ordinary drinking purposes it is quite unnecessary to perform this operation, but when water is used for brewing, dyeing, and starch-making, the presence of the alkaline carbonates is a matter of great consequence. The following method, though by no means perfect, is generally adopted. Two gallons of the water are evaporated in a large platinum dish down to about four fluid ounces. This is filtered from the deposit, colored with tincture of litmus, and then neutralized by a standard solution of sulphuric acid, containing in a hundred cubic centimeters as much acid as will neutralize one grain of alkaline carbonate.

Determination of Chlorine.—Half a gallon of water is evaporated to about four fluid ounces. Dilute nitric acid is then added to dissolve the precipitated carbonates. The whole is transferred to a beaker glass and filtered, the filter being thoroughly washed. To the solution is now poured in a slight excess of nitrate of silver, which throws down all the chlorine as chloride of the metal. The menstruum is now boiled, filtered, and the precipitate well washed with hot distilled water, then dried at 212° , ignited in a porcelain crucible, and weighed—143.5 of chloride of silver contain 35.5 of chlorine.

In determining the chloride of silver, the filter containing it should be completely exsiccated, then ignited very gently in the porcelain crucible; as soon as it ceases to burn, the carbonaceous residue of the filter should be slightly moistened with concentrated nitric acid, and again burned. By repeating this process several times, until all the carbon of the filter is destroyed, any loss of chloride of silver will be avoided; but before weighing, it is well to moisten the residue with hydrochloric acid, and ignite, in order to convert any reduced metal into chloride.

Determination of Sulphuric Acid.—Half a gallon of the water is, as in the preceding instance, evaporated to three or four ounces, and acidified chloride of barium is then to be added, and the whole boiled, and left for twelve or more hours in repose, then filtered, and the sulphate of baryta washed thoroughly and dried. 116.5 of sulphate of baryta represents 40 of sulphuric acid.

Directions for determining in Water the Non-volatile Organic Matter—Silica, Iron, Alumina and Phosphate; Lime and Magnesia.—Evaporate slowly half a gallon of water to about a pint, over a gas flame; then transfer the dish to a sand-bath, and continue the evaporation till the bulk is reduced to about two fluid ounces. Now accurately weigh a clean platinum dish. Scrape the deposit carefully from the bottom of the porcelain basin, and rub off that which cannot be removed by the platinum knife with the middle finger; rinse the whole into the platinum dish, and then evaporate to dryness on a water-bath. Be careful to observe that every particle of the deposit is removed from the porcelain vessel. When the residue is dry place the dish in an air-bath, and heat it for half an hour or an hour at a temperature of 260° .

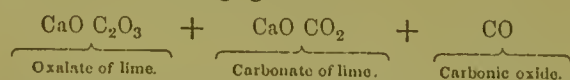
The object of heating the residue to this temperature is to expel the water of crystallization combined with sulphate of lime, which is almost an invariable constituent of well and river waters. Note down the weight. The difference between the weight of the basin when empty and that of the dish and residue will, of course, represent the actual weight of the residue in half a gallon of the water. The residuum being thoroughly desiccated and weighed, place it on a platinum triangle, over a good gas flame, or the flame of a BERZELIUS lamp, and ignite until the blackening produced by the carbonization of the non-volatile organic matter disappears, and the mineral constituents are *white*. The time required to produce this change should be carefully noted. If nitrates or nitrites be present, as is invariably the case in waters containing sewage and other animal matters, then gently facilitate combustion of the organic matter, and the residue becomes white in a few moments.

On the other hand, if the water be contaminated with organic matter which has undergone but little decomposition, and especially if urine be present, the carbonaceous residue will require very lengthened ignition in order to consume the carbon. If it be necessary to heat to redness for any length of time, some of the carbonic acid in combination with lime and magnesia will be expelled, and consequently the loss of weight occasioned by the ignition would not correctly represent the actual quantity of organic

matter. It is, therefore, necessary to *recarbonate* the lime and magnesia. This is done by moistening the residue with a few drops of a strong solution of carbonate of ammonia, and again drying it at 260° till it ceases to lose weight. The dish being now weighed again, and the weight noted, the difference will represent the quantity of non-volatile organic matter present with the mineral constituents. By the continued ignition which is necessary to burn the organic matter, the *silica* is rendered *perfectly insoluble*. To the residue in the platinum dish is now added a fluid ounce of water, and, drop by drop, strong hydrochloric acid—about one in two fluid drachms—until effervescence ceases. Particular attention should be paid to the odor of the gas evolved; if it smells of sulphide of hydrogen, this will be a further indication of the contamination of the water *by animal refuse*.

After the effervescence has ceased, the dish should be gently heated on a water-bath and the solution filtered. The silica left on the filter should be washed well with hot distilled water, till a drop of the washings, evaporated on a platinum knife, no longer leaves a trace of residue. The filter containing the silica is dried, ignited in a weighed platinum crucible until the whole of the carbon is consumed, and then weighed. The filtrate from the silicic acid, after the washings have been added, is to be neutralized and made slightly alkaline with ammonia. The iron, alumina, and phosphates of the alkaline earths are precipitated, then filtered and washed with the same precautions as given in the determination of the silica, and when dried, weighed. As the iron, alumina, and earthy phosphates occur in water in very small quantity, rarely exceeding together a grain per gallon, it is for general purposes quite unnecessary to separate them. The precipitate produced by ammonia is usually recorded as *iron, alumina, phosphates*. After the precipitate is completely affused, and the washings are added to the filtrate, the lime is next to be thrown down, and this is done by adding oxalate of ammonia in excess; allow the whole to stand till the supernatant fluid becomes bright. Add the washings to the filtrate.

The precipitate is to be dried, ignited, and weighed. By ignition the oxalate of lime is converted into carbonate, and is weighed as such. The following decomposition occurs during ignition:—



As a portion of the carbonic acid of the carbonate of lime might be driven off during the heating, it is advisable to moisten the residue in the crucible with strong carbonate of ammonia, once or twice igniting after each addition, and taking the weight when it becomes constant. Fifty of carbonate of lime represent twenty-eight of lime. The washings being evaporated and added to the filtrate, about half a fluid ounce of a solution of phosphate of soda is added, and the menstruum allowed to repose for twenty-four hours in a moderately warm place. The magnesia is thus precipitated as phosphate of magnesia and ammonia— $2\text{MgO}, \text{NH}_4\text{O}, \text{PO}_5$. This salt must be well washed with dilute ammonia—one part alkali to six of water—dried, ignited,

and weighed. By burning, the precipitate is converted into pyrophosphate of magnesia— 2MgO PO_5 —from which the quantity of magnesia is ascertained. One hundred and twelve of the pyrophosphate contain forty of magnesia.

Determination of the Alkalies.—The determination of the alkaline salts in water is generally omitted in ordinary analysis; but it must be acknowledged that when water is required for certain purposes, as for instance, for brewing, it is very important to determine not only the quantity of potassium and sodium present, but especially the form in which they occur, whether as chlorides or as carbonates. For brewing purposes it is usually considered that waters containing sulphate of lime are best suited for the manufacture of pale ales, since beers made with selenitic waters are paler than those made from water free from gypsum; but notwithstanding the presence of sulphate of lime, if potassium and sodium be there as carbonates, it is impossible to obtain a pale infusion of malt, owing to the alkaline carbonates extracting certain constituents which are not soluble in water free from alkalies. The following is the best method of determining the alkalies. Half a gallon or a gallon of water is evaporated to dryness in a porcelain dish in the usual manner. The residue is dissolved in hydrochloric acid, and evaporated on a water-bath to dryness. The soluble constituents are then extracted by water, and to the aqueous solution is added an excess of baryta water. After the precipitate has subsided, the solution is filtered, and to it is added a *very slight* excess of *pure* carbonate of ammonia. The excess of baryta thus precipitated is filtered off, and the solution which now contains only the alkalies, as chlorides, is evaporated to dryness in a weighed platinum dish, to determine the quantity of mixed chlorides of potassium and sodium. The weight being noted, the chlorides have now to be separated. This is accomplished by dissolving in water, adding excess of bichloride of platinum, and evaporating to dryness on a water-bath. The mixed platinum salts are now treated with alcohol and ether, filtered and washed with a mixture of ether and alcohol till the washings come through perfectly colorless. The precipitate of bichloride of platinum is then weighed, and the quantity of chloride of potassium it represents is calculated. This is deducted from the weight of mixed chlorides, the actual quantities of potassium and sodium calculated.

Having now determined the actual proportions of all the ordinary acids and bases present in the water, one has then to associate the acids and bases together as salts, in the form in which they probably existed in the water previous to analysis.

The association of the acids and bases is founded entirely on arbitrary rules, the usual plan being to unite them in the order of their respective affinities—the strongest acids with the strongest bases. But this is obviously an incorrect method, since it is often found that two chemists analyzing the same water will give entirely different forms of analysis, although they may both have found the same proportions of the respective acids and bases; the one will associate all the sulphuric acid with potassa and soda, the other may place it with

lime, and regard the alkaline bases not as sulphates but as carbonates. Now, as before shown, it is a question of the greatest importance, when water is required for special purposes, to determine not only the proportions of acids and bases present, but the form in which they are associated. In order to do this properly the analyst must have regard—1st, To the geological characters of the source of the water; 2d, to the nature of the country through which it flows; 3d, to the contaminations from sewers and manufactories to which the water is exposed.

Rain-water, it is to be presumed, cannot differ materially in the nature and quantity of its impurities, but yet it has been shown that one rarely finds two river waters of precisely the same composition. In the water of the Dee, the analyst finds only about four grains of mineral matter, because the rocky soil over which it flows is soluble only to a slight extent in native water. The water of the Trent flows over a soil abounding in gypsum, and consequently the water is very hard, while in the water of the Thames, which flows through a line of country composed essentially of chalk, the prevailing constituent is bicarbonate of lime. The presence of a superabundance of earthy salts in water, exercises an influence of some importance in many of the industrial works of the kingdom, and especially in brewing. Paradoxical as it may seem, it is now an ascertained fact, that the hardest waters, that is, such as contain most earthy salts in solution, have the greatest extractive power for the brewer; and further, that the chemical changes that take place between certain constituents of the malt and those salts, serve in the case of ale brewing to fine the beverage in the natural way, without the aid of disgusting and corrupt *stuffs* employed for this purpose very frequently.

A glance at the composition of the waters which are used by ALLSOPP and BASS, the Great Burton brewers, and by TETLEY, of Leeds, *et cetera*, gives at once the clue to the superior excellence of the manufactures of these parties over ales made from such liquids as the *Liverpool Pike*, which is not only devoid of earthy salts in the requisite quantity, *but contains an amount of animal and vegetal matter in such a state of fermentation*, that the action is engrafted on the glucose, and proceeds in the tun collaterally with the alcoholic fermentation, which it ultimately modifies into the lactic and acid fermentation long after the natural ferment—the gluten of the malt—has been thrown off:—

	Burton water, Dr. Bottinger, Allsopp's brewery.	Leeds water, Tetley's brewery, Editor.
	Grains.	Grains.
Carbonate of lime,	15.51	19.78
“ magnesia,	1.70	0.93
“ protoxide of iron,	0.70	4.97
Sulphate of lime,	18.96	—
“ potassa,	7.65	13.09
“ soda,	—	9.73
“ magnesia,	9.95	7.11
Chloride of sodium,	10.12	4.74
“ magnesia,	—	1.72
Silica and loss,	0.79	—
Total per gallon,	65.28	62.07

The quantity of calcareous salts in the above waters is a proof of the beneficial action of lime in the preparation of the best malt liquors.

ELECTRICAL PROPERTIES.—This article on water

would be incomplete without making some allusion to its electrical properties, which are not only turned to useful account in the numerous and increasing applications of electricity, but also perform an important part in the great phenomena of nature. It would be improper, perhaps, to particularize under this head the hydro-electric machine, because although in that apparatus very large quantities of electricity are generated by the issue of steam through narrow apertures, the effect has been attributed by FARADAY to mere friction, and therefore exhibits no new property of the water itself. It is in the electricity which it generates by contact with oxidizable metals in the galvanic battery, and in the variable conducting power of the liquid according to its greater or less admixture with different acids and salts, that water assumes its chief importance in electro-chemical action. In the working of the battery, for example, it is the decomposition of the water which accompanies the oxidation of the zinc or other positive metal, and not the action of the acid or salt superadded, that really produces the electricity. This was demonstrated by KOHLRAUSCH, who showed that the electric tension was the same at the poles of two similar batteries, one of which was charged with distilled water and the other with a mixture of water and sulphuric acid. The remarkable effect of certain acids and salts in increasing the energy of the current, is chiefly due to the peculiar property which they possess of increasing the conducting power of the liquid. The following table exhibits this property in a very striking light:—

	Conducting power
Distilled water,	0.0125
Do. with 1-20,000 of nitric acid,	0.075
Sulphate of copper, saturated solution,	5.42
Sulphate of zinc, do.	5.77
Nitrate of copper, do.	8.99
Chloride of sodium, do.	31.52
Sulphuric acid diluted with eleven measures of distilled water,	88.68
Nitric acid, specific gravity 1.31,	93.77

From which it appears, that the addition of only one twenty-thousandth part of nitric acid to distilled water increases its conducting power about sixfold, and that one measure of sulphuric acid, added to eleven of distilled water, increases its conducting power seven thousand times. Distilled or absolutely pure water is therefore a very bad conductor of electricity; but it has been shown that water of this extreme purity is not to be found in nature; that even rain-water is more or less impregnated with certain foreign ingredients, and that the waters of rivers and wells vary immensely in the amount and character of their saline constituents. It is therefore that, in rainy weather, the moisture of the atmosphere, acting the part of a conductor, destroys the insulation of the telegraph wires, and obstructs the working of the instrument; it is therefore that the earth, and still better, the briny waters of the ocean, not only transmit natural currents, but submit themselves as willing agents to the purposes of telegraphic communication; and lastly, it is to the moisture of the atmosphere, floating in clouds charged with an opposite electricity to that of the earth, that the grand phenomena of the thunderstorm chiefly owe their existence.

WINE.—*Vin*, French; *Wein*, German; *Win*, Anglo-Saxon; *Wijn*, Dutch; *Vino*, Spanish and Italian; *Vinho*, Portuguese; *Vinum*, Latin; *Oinos*, *Οινος*, Greek. —All these denominations were probably derived from *Oinos*, with the digamma prefixed, answering to F or V in English, as *Voinos* and thence the Latin *Vinum*. The Hebrew term for wine in general, is *Yayin*, but if medicated or, in other words, made more potent by the admixture of herbs or drugs, it was denominated *Shekhar* or *Strong Drink*, in common with other fermented liquids. The Greek name being the parent of the Latin, confirms the tradition that wine came into the more Western parts of Europe from Greece by way of Italy, and from Asia into Greece.

When man was driven from that peaceful asylum originally assigned to him by his Creator, and condemned to earn his bread by the labor of his hands, his attention was no doubt powerfully exerted in procuring the necessities of life; such as food, clothing, and habitation. As a cultivator of the earth, he must have been constantly employed, and, as his occupation varied with the seasons, his mind was continually disciplined on contrivances to diminish and sweeten his toil. His activity, when thus excited, soon extended its influence to every department of life, and having procured its necessities, he was doubtless early led to task his ingenuity in the attainments of its luxuries. Among these, the preservation of fruit and their juices, however rudely practised, might have led to the use of inebriating drink—a beverage which was discovered by some of the most savage nations, and is deemed a luxury by the almost universal testimony of mankind.

Wine, when an uncompounded word, signifies the fermented juice of the grape only; but when compounded, it is applied as a general term to the fermented product of other fruits in conjunction with the name of those fruits, tendrils, stems, leaves, or similar substances from which it is made, as gooseberry-wine, ginger wine, and all the varieties denominated *domestic* wines.

Wine of the grape is divided into dry and sweet, and under one or the other of these great divisions every variety is included. The characteristics and causes of each of these divisions will be fully explained.

The juice of the grape, which is usually called *must*, is known to ferment *per se* at 70°, which proves that wine was very early known, particularly in hot climates, where drink is so much required to allay thirst; and this is a further sign that the vinous fermentation was familiar long anterior to the deluge.

Carrying this idea still further towards the Creation, MILTON seems to have entertained the opinion that the fruit of which ADAM and EVE had eaten—

— whose mortal taste
Brought death into the world, and all our woe,
was of an intoxicating nature, when he says:—

Soon as the force of that fallacious fruit,
That with exhilarating vapor bland,
About their spirits had played, and inmost powers
Made err, was now exhaled.

Wine is the oldest fermented liquor, its invention being ascribed to NOAH in the traditions of the Jews

almost immediately after the deluge. The Greeks and their fabled DIONYSUS from Egypt, originally from India, threw no light upon the discoverer; but if they learned the art of making wine from the Egyptians, that liquor may be thus traced up to the days of MOSES. HERODOTUS reports that there was no wine made in Egypt, a singular error, when Maronic and Tunic wines were notorious. The wine of Meïœ called *indomitum* by LUCAN was far-famed. The writings of MOSES show that the kings of Egypt drank wine, as all who have perused them will not fail to recollect in reading the story of JOSEPH and the chief butler of PHARAOH. The ruined temples of Thebes also display the emblem of the vintage in bas-relief, and figures of men pressing grapes with their hands, the must flowing into gobbets emblematic of the wine-press. Some have used this as an argument against fermented wine; but must unfermented, would not keep from decomposition for many hours, even in the Eastern land of miracle: nor would the simple juice have intoxicated NOAH, because to occasion ebriety fermentation is absolutely necessary, as in all other alcoholic liquors.

Next in antiquity to the volume of the Jewish faith are the works of HOMER and HESIOD, who lived so near together in point of time, that even concluding HOMER to have flourished in the tenth century before CHRIST or about the reign of SOLOMON, the difference so much discussed by the learned is of no moment in a scientific sense. HOMER mentions the names of several kinds of wine, and alludes to their potency.

The frequent allusion to wine, the praises bestowed upon it, the flowing goblets, the luxurious banquets as described by the great Grecian poet one thousand years before the Christian era, exhibit its value and its attachment to the comforts of the table and to jovial society.

HORACE was of this opinion when he says—

Homer, in praise of the profane,
No doubt loved well the balmy juice.

The wines referred to required twenty parts of water to make them potable, as in the case of the Maronean ones. Poets are not to be literally trusted; and in the present case, as the object of HOMER was to intoxicate the giant POLYPHEMUS through his hero ULYSSES, full latitude must be given for poetical fiction, which can seldom be quoted in reference to the exact sciences. This Maronean wine was made from vineyards on the side of Ismarus, a hill of Thrace, by MARON a priest of the Sun. The circumstance of the Greeks mixing water with their wine, might after all mean no more than it does in France at the present time, where water is often mingled with common wines of the country by no means remarkable for their strength. Thus the wine of Scyathos is said to have been used with half its bulk of water. The wines most in repute with the Greeks were, in the first place, the wines of Chio or Chios, which, with the Thasian, were ranked among the superior growths. Lesbos was also celebrated for its wines. Many of the Greek islands were distinguished for wines of delicacy and flavor, for the most part rich and sweet. The Arinsian wine of Chio was in high esteem as a luscious

product of one of the vineyards of the island. The Pannonian was celebrated for its healing qualities. This wine was red, from a vineyard in Lesbos. The wines of Rhodes, Crete, and the Clazomenian from the shores of Ionia, were much valued, and often taken with an admixture of sea-water, a singular custom, thought to impart smoothness to the wine. The quantity thus mingled was very small, and was always boiled before it was mingled with the wine. The Greeks classed their wines, as in modern times, into sweet and dry, but had an intermediate species. They seem to have preferred the thick sweet wines to all others, that species, for example, which the moderns denominate malmsey, differing little perhaps from the modern wine of Cyprus, or the malvasia of the Morea. Some of these wines possessed what is now called the bouquet. As soon as they were opened to the air, the perfume was immediately perceived, but this might have arisen from the infusion of odorous substances at the time of fermentation, a practice then common. Sappian wine was one of those celebrated for its odor on being uncorked. This odor, it is pretty clear, did not arise, as it does in the pure wines of France in modern times, from the natural perfume after fermentation, but from the addition of odorous substances. Port and the strong Anglo-medicated wines at present, possess no bouquet from its being destroyed by the admixture of alcohol with them artificially, rendering them heavy and dull. The wines of Bordeaux, Champagne, and Burgundy, on the other hand, have the perfume in a high degree from nature.

The wine of Chio, called the Phanean, was celebrated among the Romans, who imported both that and the wine of Argitis. The wine of Mende in Thrace was a white wine of no great strength. The wines of Zante speedily intoxicated; and those of the other Greek islands, as well as of Lydia, Phœnicia, and Cilicia on the mainland, were of good quality, producing growths the mere names of which it would be superfluous to record.

Rome, as she learned the other arts from Greece, acquired also that of making wine, as soon as she extended her power beyond the limits of her home empire. In the days of HOMER milk was substituted in the sacrifices in place of wine, because of its scarcity at Rome. The wine first made seems to have been from the grape grown in the Campania Felix. The most celebrated sites for the vine were near Naples, on the sides and at the foot of Vesuvius, now covered with the lava and ashes of that celebrated volcano; a spot in which Bacchus was said to have delighted in consequence of its rare fertility and excellent adaptation for the vine culture. The sea washes the limits of this beautiful vine-climate in one direction, and in the other delightful hills, named the Falernian, Surrentine, Massic, Gaurean, and others, arose with the choicest aspect and the most propitious slopes from the low country, giving names to the products since wedded to immortal verse. Thus the Falernian, Surrentine, Cæcuban, Setine, and other wines of the vicinity, were named from their native hills. One or two of the more celebrated writers left passages in their works which enable us to give a guess at the nature of some of the wines in use among the

Romans, whether the growths of Greece or Italy. It is certain from these that, except in the sweet wines of the South of Europe at present, no great similarity could have existed between the ancient wines and those most prized by the moderns. The writings of ATHENÆUS and PLINY give a tolerable account of the treatment of the vine under cultivation, but we learn little from them in relation to the constituent parts, flavor, or qualities of the produce. The same remark will hold good in relation to the extant works of VARRO, CATO, COLUMELLA, and PALLADIUS. In short, no source remains from which any tolerable approximation can take place as to a knowledge of quality and flavor. It is well known on the other hand that the Campanian vine once enriched a considerable territory of great fertility, and that a number of large towns which have now disappeared, once adorned that favored spot. The more famous wine was the Falernian, which some suppose to have been made on the present Monte Barbaro. The Cæcuban, a sweet wine, was made on the palmy lands of Amycle. The Falernian was of three kinds, the dry, sweet, and weak. A celebrated vintage called the Opimian, from the name of the consul that year, L. OPIMUS NEPOS, took place in U.C. 632, the wines of which bore a great price a century afterwards. The Falernian required nine or ten years to ripen, and when aged was bitter. Some have imagined it was a dark red wine, others that it was white. The Surrentine wine was durable, and generally taken out of cups of the same name. The Massic came from Sinuessa; Trifoline from a hill near Naples; Tarentine from Mount Aulon, near Tarentum; Alban from a hill near Rome; Mamertine from Sicily, near Messina; Cereton from Etruria; Signian from Latium; and Massican from the Abruzzo. The vicinity of Rome also produced the Nomentan, Sabine, and Venafran wines. The north of Italy produced no wines of note. Spain sent the wines of Tarragona to Rome, and France those of Narbonne, Marseilles, and Vienne; but these were said to flavor too much of the smoke of the *fumarium*, or else of pitch.

The Romans suffered their vines to grow high and weakened the must. How the fermentation was managed nowhere appears. The wines were placed in a smoky receptacle to ripen, the object being the same in ancient as in modern times, to assure maturity. The Carthaginian MAGO, who wrote five hundred and fifty years before CHRIST, says, that to make the best wine, that of the sweet or luscious species, the bunches of grapes were gathered when shrivelled by the sun's heat, the bad fruit picked out, and they then were placed upon a frame of open-work covered with reeds, exposed to the sun by day, but sheltered from the dew at night. When they were sufficiently shrivelled they were thrown into a cask and trodden, and thus the first must was made. When drained, they were submitted to the wine-press for the first wine. They were then trodden a second time, and cold must added to the pressing. This second wine was placed in a pitched cask, to prevent it from becoming acid. After it had remained for twenty days in this state it was racked into another vessel, closed up from the air, and covered with a skin.

Such was the ancient mode of making sweet wines of the luscious malmsey species. For the wines in general, the fruit was gathered at intervals as it ripened, and carried to the press in baskets. The must was received in a stone or plastered cistern, and the fermentation was completed as quickly as possible. The process, there is reason to believe, was not very different from that hereafter described. In certain cases the fermentation appears to have been unnecessarily prolonged, and a part of the must that flowed from the grapes by their own pressure was reserved in a separate vessel and set aside, as it is the custom to do now in making Tokay-Ausbruch in Hungary. This must, the most valued, was often stored by itself. Sometimes it was plunged, when in a state of fermentation, into deep water, being previously hermetically sealed. Weak must was often boiled down, so that much of the aqueous portion evaporated, and it was denominated according to the quantity of the portion unevaporated. If two-thirds were left, it was called *calenum*; if only one-third, *sapa*. This was evidently copied from the Greeks, and is still practised, being called in Italy *vino cotto*, and in France *vins cuits*.

The custom of adding sea-water to wine is said to have been discovered by accident. The water was boiled down to a third part, but the quantity used differed according to the nature of the wine. The act of perfuming the wine must have ruined its delicacy; pitch, rosin, cassia, myrrh, saffron, and cypress leaves were, one or the other or several of them, thus infused. The true principles of fermentation were evidently unknown to the ancients, who had not the advantage of modern chemistry. It was the same with the causes of the difference between dry and sweet wines. There was no deficiency in the attention paid to the vines, except that they were permitted to weaken themselves by too luxuriant a growth; this in consequence tended to aid acetous fermentation. In aspect, soil, grafting, and training, all seems to have been well known in ancient times; the Greeks understanding this point better than the Romans. The Aminean grape was the species most cultivated for wine, at least in the Campania Felix, but it cannot be identified with any modern species. October was the vintage month.

The treatment of the ancient wine after the first fermentation included a further progress in the vat, and it was then placed in earthen vessels, hermetically sealed, denominated *amphora*, each of which held 6·7827 English gallons, or in other vessels of a different capacity, as the *urna*, which held just half the quantity of the amphora. If an inferior wine, or one designed to be carried to a distance, it was placed in pitched skins—the bottles of the New Testament. When designed for the amphora and cellar, after being exposed to the smoke of the *fumarium*, it had the year of the vintage or the consular year marked upon it, and was set in the ground. Under this treatment in the *fumarium* and elsewhere, some of the wines grew so thick that they could not be drunk until they were dissolved in water. That sometimes the wine tasted of the smoke is not matter of wonder. It is well known that Madeira ripens rapidly if the bottles are plunged into a hotbed or into stable dung. The amphoræ were

vessels without bases, shaped as in Fig. 615, and made of pottery clay. The consulship of the famed Opimian year is marked on some of the existing amphoræ in the way thus exhibited—L. O. NEPOS, U.C. 632. The wines of the ancients were thus different in quality from those of modern times, and could only have been relished by long habit. The different varieties which have been transmitted by name in Italy, Gaul, and the East are reckoned at a hundred kinds, rough, soft, and sweet. That the wines of the ancients were more durable from this after-management than from any knowledge they possessed of their chemical combinations when treated scientifically according to their nature, and unmingled with substances foreign to them, is evident upon a due consideration of the subject.

Regarding the wines of Asia Minor, little is known in respect to the treatment. Some kinds were kept in the *fumarium* until they became as hard as salt, and it was necessary to dissolve them too in water before they were drunk. The prices they bore, considering their age, were not extravagant; those more than a century and a half old costing less than seven shillings the English quart. In Rome the quantity of wine consumed was considerable. The servants of CATO were allowed about a pint and a half per day. The stocks of the more precious wines kept by the opulent were surprisingly large. Of the best and dearest Greek wine, that of Chio, HORTENSIVS left ten thousand casks at his decease. The celebrated MÆCENAS introduced a rare wine of his own, called *mæcenatianum*. Of the common wine made in Italy, too, the produce was large, being in one recorded case no less than two thousand one hundred and fifty gallons per acre, or eight *culei* on the jugerum or twenty-eight thousand eight hundred square feet. In these computations, however, there is much uncertainty.

Wine was drunk in Rome out of murrhine cups when the eternal city was in its greatest height of luxury and pride. What this substance was is unknown, but it appears to have come from Egypt or the East, and to have possessed an inherent perfume; many dissertations have been written upon its nature, all alike unsatisfactory.

Among names of ancient wines, is that of Helbon or wine of Tyre, called by the Greeks *kalibonion*, and alluded to by the prophet EZEKIEL—the name meaning sweet or fat; it was made near Damascus, originally by the Persians. This wine was common in England in the reign of RICHARD III., being imported in Venetian vessels. The wine of Lebanon in HOSEA, is praised for its perfume. But the different conjectures regarding the nature of ancient wines, built upon no satisfactory data, cannot, any more than their names, be of any real moment, however amusing to the scholar. It may be observed, however, that a marked distinction anciently existed between pure wine, and that which

Fig. 615.



was perfumed or medicated, as with certain wines imported into England, brandy is added for the same purpose, particularly to port wine. The Jews have preserved this distinction in scripture, by using the term *mixed* or *strong wine*; thus—In the hand of the Lord is a cup, and the wine is red; it is *full of mixture*; and he poureth out of the same; but the dregs thereof, all the wicked of the earth shall wring them out and drink them.

Leaving a subject so much of which must be conjectural, the wine of the present time, naturally the most important, comes to be considered, together with the processes adopted by the moderns in its manufacture. The variety of the plant which produces it, and the nature of the soils in which the best grape is matured, are subjects copiously treated of both by French and Spanish writers. In the catalogue of the national collection of vines at the Luxembourg in Paris, there are five hundred and seventy varieties, classed black oval, black round, white oval, white round, grey and violet oval, and grey and violet round. CHAPTAL collected fourteen hundred sorts, and CLEMENTE states that two hundred and fifty species exist in Andalusia alone. The treatment of the vine and the entire culture of the plant belong to the rural economy of the wine-producing countries. To enter largely upon this subject would be out of place here; still the following on the kind of soil best adapted for the grape, and on the best description of grapes to employ, will interest and instruct the reader.

The wine-producing countries in the Northern hemisphere are included between the parallels of 33° and 51° North; but this rule is limited by local circumstances, probably by the line of the biting North-east winds, which keep back the vine in spring. An oblique line drawn a little north of Coblentz, concave to the North, and continued to the mouth of the Vilaine, in 47° 25' North, will nearly define the vine limit. Wine once made in good quality at Estampes and Beauvais, so as to be celebrated, cannot be made there now. Thus it was once made too in the counties of England South of Cambridgeshire. Wine in 1553 was made of the muscat grape at Mâcon in Burgundy, where it cannot now be made at all. In Asia no good wine is made South of latitude 33° North, in Persia and Shiraz. In regard to the Southern hemisphere, except a little sweet wine from the Constantia vineyards at the Cape of Good Hope, none of any mark is yet produced, though much of an inferior quality is made. With the wine-producing countries of the North the world is too familiar to need the exact enumeration.

Keeping in view wines of the first and second class in excellence, nearly all which lay claim to the greatest delicacy and purity are produced in France, where science and long experience have been brought to bear upon their management. In a first-class wine there must be no mixture of any foreign matter whatever. The fermentation must be natural, and no extraneous substance introduced, not even brandy. Nothing must be allowed to prevent the development of the perfect character of the particular species expected—lightness, freshness, a rich odor conferred by nature, such as are found in Romanée-Conti, Chambertin, Vin du

Roi, or Hermitage of the first class, because of such wines only can the term *pure wine* be understood, or a standard be found by which the first-class can be established, and the test be fixed for the inferior kinds. France, Spain, Germany, Italy, Portugal, Hungary, Greece, and Sicily are the principal wine countries of Europe. Tolerable wine has also been made in the extreme South of the Russian dominions.

Passing over the vine culture, the best sites, the diseases of the vine, the training, and the incessant and laborious calling of the vine-dresser, all belonging, as before observed, to rural economy; and therefore only observing that the practice of grafting is pretty general—it may be added that some vines will bear well for a century and a half. There have been examples of three centuries, while others will not be productive for more than forty years.

The extent of the vineyards that produce the finer wines is well known to be very limited. The differences of soil and treatment do not appear sufficient to account for this fact. Although the best vines are grown on a calcareous soil, as on the chalk hills of Champagne and the albarizas of Xeres, of which carbonate of lime forms two-thirds, and in three-fourths of the more celebrated vineyards this is the case, though the necessity of such a description of soil has been denied.

In the vineyards of Andalusia, while some of the above soils contain even seventy per cent. of carbonate of lime, the remainder is a compound chiefly alumina, with a very small portion of silica, and sometimes a little magnesia. In certain spots the soil is almost pure carbonate of lime. This kind of earth absorbs every particle of moisture which falls upon it, and never cracks nor opens in the hottest summers. The albarizas are a series of calcareous hills. The best Spanish wines produced on such a soil, exhibit its virtues very strikingly in the fineness and durability of the product, and militate against the opinion expressed in some districts, that if the soil be porous, light, and free, the presence of lime is of little moment. The fences of the vineyards on the albarizas consist of the prickly pear. Adjoining the albarizas, or chalky soils, come the arenas, or sands; but these are intermingled, more or less, with calcareous particles. About Malaga, where the surface of the country is extremely rugged, the soil consists of limestone, intermixed with slaty schist, over which the rich raisins for export are produced. In the South of France, in Rousillon, the soil resembles that of Malaga, particularly near Perpignan, being slaty schist, or gravel, interspersed with calcareous matter. In some places where the soil is not six inches thick, a hole is bored in the loose rock with an iron bar, in depth about a foot, into which the plant is thrust, among the stony and arid ground. In Burgundy the soil varies much. At Chambertin it is a brown loam, full of gravel, and friable. This gravel consists of small pieces of broken limestone, in some places; in others, of marl with small shells—while, in another place, the vines grow in pure clay, but still with traces of lime in some form. The champagne district, in like manner, is almost wholly calcareous, at least where the best wines are made. Thus the famous sillery is produced from vineyards on chalk,

with an Eastern exposure. At Ay, on the Marne, on both sides of the river, the hills are chalk, and the soil often supported by terraces. *By the river of Marne, and on the hills of Rheims are the celebrated localities*—proverbially so. The chalk, whether it lie deep or superficial, produces the same effect in respect to dry wine of superior quality, agreeably to its treatment and the aspect of the vineyard. The hermitage wine has been cited in proof of the goodness of wine grown on the debris of granite.

Wines of the finest quality are undoubtedly grown upon soils where lime is not immediately visible. Sands in the vicinity of Bordeaux, and granitic soils near the Rhone, flinty and argillaceous earths, are found to produce excellent wine. But hermitage, for example, although produced from vines grown among fragments of granite, is no doubt affected favorably from the calcareous soil hard by, having portions intermingled with them; nor can it be any exception to the fact as respects the finer dry wines, that their superiority is due to their connection with calcareous matter. Sweet wines are produced in almost every kind of soil. Dry wines produced on schist, for example, are poor, compared to those the fruit of which is grown on chalk land; while the sweet wines, such as those of Malaga, are good on that description of soil. The Rivesaltes, a sweet wine of France, is produced on granitic land upon which lies a stratum of pebbles, while the dry wines of the same land which produces those celebrated growths, are sufficiently mediocre. At Ay, where the finest champagne is made, the soil lies upon chalk in some places from ten to fifteen feet thick; but the superincumbent earth is full of pieces of chalk, the surface only being argillaceous; and where most so, causing some difference in the quality of the wine. Very little manure is applied to the vines that produce the best and finest wines. In argillaceous soils the roots of the vines are found not to branch off in a desirable manner; and the facility with which the soil retains the water, causes a degree of humidity prejudicial to the bud. Volcanic soils, on the other hand, give excellent wines, particularly when they are of very ancient date, and rival those the fruit of which is grown on calcareous strata; generally, too, possessing a flavor peculiar to themselves. In all cases the soil must be light, friable, porous, so that water shall not lodge around the plant. The exposition may vary. *Bacchus loves the hills* is an old, but not an unexceptionable adage, as gravelly plains may produce good wines. Sometimes, according to the nature of the country, an Eastern aspect is best; at others a Southern, and even a Northern has yielded excellent wine; much in such a case depending upon the latitude and the more obnoxious winds, as well as the atmospherical temperature. It is remarked, however, that good wine is rarely produced in narrow valleys, especially if a river flow through them.

It will thus be perceived that the nature of the soil for the dry and finest wines must be calcareous, even to pure chalk; in all events it must be sufficiently so to influence the vine most essentially during its growth; and that for sweet and luscious wines, the nature of the soil is of far less moment, such wines being grown

on every kind of soil, except that which produces the most valuable and rare dry growths. In the British colonies, and in the United States of America, not long ago covered with primeval forests, the soil, enriched by the autumnal spoils of ages, is too good for the vine, the fruit of which, for making good wine, differs so much from the character of fruit in general, when intended for the table.

The grapes are various that give out the more precious must. In Ronsillon in France, the best wines are from the carignan, grenache, and mataro grapes. The celebrated Rivesaltes wine is principally from the white macabeo, the muscat, and grenache blanche; the hermitage comes from the scyras or cins grape, the roussette, and the marsan. The pineau blanc and pineau noir before mentioned produce the celebrated Clos Vougeot wine in Burgundy. In the Bordeaux wine district, the Graves, Barsac, and Sauterne, come from the white sauvignon, the semillon, the rochelin, blanc-doux, and primeras—all three white—and the black muscade. The best Spanish wines are the produce of the pedro ximenes grape, both at Malaga and Xeres. At Malaga and Grenada one half the plants are of this species; at Xeres, one-eighth; at Motril, four-fifths; and at Paxarete, one-fourth. The grape, giving fine wine in the North, may be productive of wine of very moderate merit in the South. In consequence every country, and even district of the same country, differs in the variety of the fruit prepared. This arises naturally from the circumstances of the temperature and soil affecting one species more than another, for which it may have less affinity. The growths are often mixed. Thus the marsan grape of itself gives a sweet wine, and the roussette or roussette a dry, therefore they are mixed to prepare the white hermitage, for example. In Burgundy the black pineau is much used, as well as the chandency. In champagne the norien and pineau prevail, with some of the gamet and gibaudot. The black morillon, and the magdelaine, and the meunier, are early bearing species. The chasselas, supposed to have come from Cyprus, the ciontat or black grape of Corinth, the muscat noir, isabelle, verdet, and black muscade, the carbenet, violet, and corinth in France, the Uva del Rey, the mollar, the listan of Xeres, the larga and doradillo, with the moscatel gordo, are used in different proportions in some places in Spain, but one kind rarely or never alone. To enumerate and describe the five hundred and seventy species in the garden of the Luxembourg in France, could not enable a cultivator to discriminate what species would be best to adopt, so much depending upon site, climate, and annual temperature. The grenache blanche, for example, is only used in the district of Collioure in France. The Hungarian varieties also are numerous; but site and experience can alone determine, as elsewhere, the species most in accordance with the views of the cultivator in producing the best wine.

By a remarkable peculiarity, nature, and habit of the vine, it adapts itself to those parts of the country which are least fitted for the cultivation of the cerealia. Those vines which bear the best fruit for the finest dry wines, invariably grow on soils which would be unproductive

with respect to the food crops. Gravel, sand, volcanic debris, flint, and such like soils, are favorable to the growth of the vine, whilst rich, deep, warm, fat earth, and all rich lands, are unsuited.

The names of the different kinds of vine fruit in Hungary are so untranslatable in the West of Europe, and so far off, that they can hardly be identified with those of the West without inspection by qualified cultivators. Thus the Furmint is used in making the Tokay-Ausbruch in the Hegyallya; the Fejér-Szöllő of the same district; the Szemendrian or white Servian grape; the Súr-Fejér or honey grape, believed by some to be the magdalen; the Balafant, the Rók-Szöllő or silver white; the Zapfner which, some contend, is identical with the Orleans of the Rhine; the Hárs-Levellő or linden-leaved; the purple Kadarka or real Hungarian; the Blue of the Banat, the Csoka, or Sloebblack, and a great variety of others, which it would be useless to name, are grown to produce the celebrated wines of Hungary.

The climate of Hungary is peculiar, and in extremes; so that, in some places, they are obliged to bury the stocks to keep them from the cold. The cellars are badly built in many places, and the casks too small, and new and unseasoned wood is continually adopted, spoiling the flavor of the wine. Marble store-vats are used in many places; one at Ofen will contain thirty-nine thousand gallons. That wines ripen best in a large volume, is proved in this district by these vats, or rather cisterns. The wines of the plains are inferior to those of the hills from the same description of fruit.

In Germany, the Riessberg, a small white grape; the Kleinberger, a very productive species; and the Orleans grape—make the more celebrated wines. The Orleans is the favorite at Rudesheim; but all the other wine-makers, except at that place, throughout the Rhinegau prefer the Riessberg. The grapes for the Joannisberger of the first class are carefully selected, and only a small quantity is ever made; about sixteen aums of thirty gallons each. The black pineau of Burgundy, and the teinturier are grown on the Rhine, as well as the chasselas. The traminer, white clävener, franken, gutadel, frühroth, black clävener, and muscatelles, are cultivated to a considerable extent in Germany, and on the Moselle, where only the kinds adapted for a Northern class of wines ripen well. This may suffice to afford a faint idea of the great extent to which that portion of wine-making connected with agriculture must be carried, to embrace the entire subject over an extensive and ever varied field.

The grapes depending for perfect maturity upon their Northern or Southern latitude, the vintage takes place accordingly in September or October. Upon the excellence of the must rests the purity of the wine, and that depends much upon the season, the character and soil being the same. The utmost development of saccharine matter is watched until the fruit is ready to burst with ripeness, if all goes on well. The sun having dried up the dew, the work commences; the gathering being expedited most in warm weather, because the fermentation is then most active; and it is desirable to ferment at once the largest possible quantity of must.

The riper clusters are separated from the branches when the skin is thin, transparent, and not apt to break between the teeth; when the color is become deep, that is, when, if the grape be of a white sort, it becomes grey, or if red, from a violet hue appears black; when the stem is woody in fibre, losing its green color, and becoming brown like the main stock, the grape hanging loosely; lastly, when the grain gives way easily to the pressure in gathering, or when crushed, has a vinous odor. The bunches are gathered with great care, for which purpose scissors are commonly used, in order to shake the fruit as little as possible; as the ripe grapes are easily detached, and are bruised with the slightest fall. The baskets—Fig. 616—in which the bunches are placed are small; and the deposition in them takes

Fig. 616.



Osier baskets and mode of carrying the grapes to the press.

place with great care lest the fruit be injured. With large baskets the grapes are crushed; and the must is too often wasted, owing to the superincumbent weight. All the bad or green grapes must be taken off and put aside, as the unripe are apt to impart acid to the sound must. The grapes in different states of maturity are not to be mingled, because they cause an inequality in the fermentation of the must by their acidity, and consequently it is deteriorated. The baskets of osier of a peculiar make are carried to the press strapped on the backs of men, or in carriages. The backs of men, or even of animals, are preferred to carriages, because the motion is less. The stems of the clusters are cut short off. Some farmers take the grapes off the clusters, an operation in France denominated *egrappage*, but the practice is by no means uniform, nor is it universal.

The next part of the process is treading the grapes, or breaking them with machines, before they are set to ferment. This operation facilitates the fermentation. Square troughs are used, having holes in the bottom to admit of the must flowing out. The grapes are then trodden by men with sabots or wooden shoes, at the best, though an ancient, a clumsy, and not very agreeable operation. The must which escapes is thrown into the fermenting vat either with or without the muck, as may be required; and the same operation is repeated until the whole is trodden. The disengage-

ment of the coloring matter from the skins is mainly effected by this process, and no substitute would answer which did not obtain that object. The subsequent fermentation and the heat it produced would not alone obtain and fix the color; the skins must be broken. Several inventions have been exhibited and others carried into practice to meet an end so desirable. Of these machines at a reasonable cost, one is the invention of M. ACHER of Chartres, and has the recommendation of being among the cheapest. This machine is shown in Fig. 617. It does its work well, having the recommendation of the more experienced of the wine-

Fig. 617.



makers that it was capable of giving the must the utmost effect of which it was susceptible, before submitting the grapes to pressure. All were found to be equally and uniformly crushed—none escaping the action of the cylinder. By its use the fermentation proceeds in a more uniform manner, and the action of the press becomes more effectual. A, a hopper in which the grapes are placed; B, a cylinder, one metre in circumference, and sixty-five centimetres in length; it is armed with small nails; the heads large and flat, placed in curved or oblique lines on the cylinders, distant from each other five millimetres. This cylinder is placed beneath the hopper, to crush effectually all the grapes which descend to it. The cylinder is turned by a handle, D; E is a species of wooden flap armed at the lower edge with a series of teeth, perpendicular to the axis of the cylinder, disposed in such a manner as to play between the nail heads on the cylinder, and to crush all the fruit which approaches it; F, the vat which receives the must when crushed.

There is another French invention for the same purpose by a mechanic of Toulouse. It consists of two

horizontal cylinders, which act in the same mode as those of a laminating engine, not only by pressure, but by friction. It moves by means of two toothed wheels attached to one end of each cylinder. In order to communicate to one cylinder a movement more accelerated than that of its fellow, the diameter of each wheel as with its cylinder, is different. A handle is fixed to the end of the smaller cylinder. The larger is ten inches in diameter; the smaller six. These two cylinders are placed at the bottom of a hopper, in which the grapes are deposited. The whole is constructed over a cask or vat, five feet nine inches in diameter, or in length, if of a different form from that of a cask, and this receives the must. It is effective, and dispenses, equally as well as the machine of M. ACHER, with the old uncouth mode of treading out the fruit with sabots.

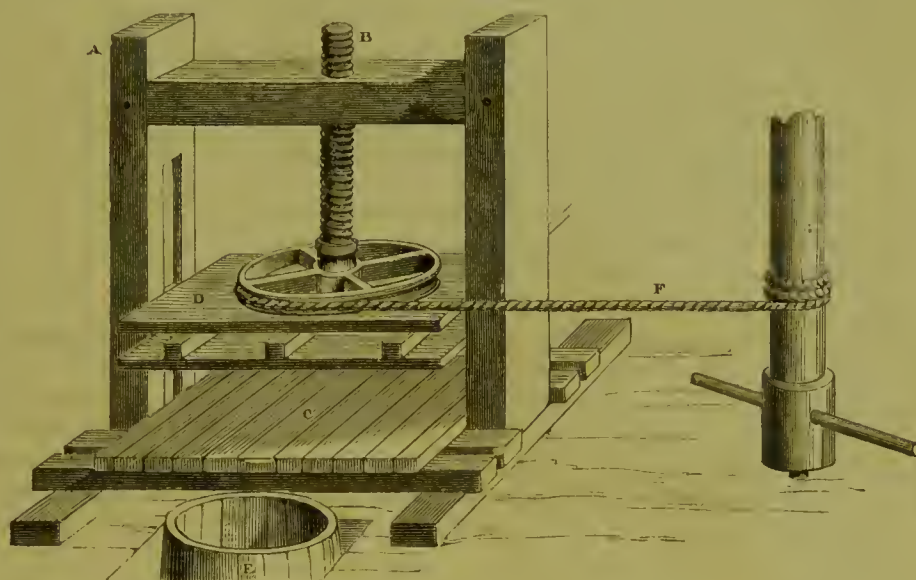
In order to prevent white wine from becoming colored, the red grapes are not trodden, because it would bruise the skins and discharge the coloring matter; but they are submitted to the press, as they arrive from the vine, and then taken to the vat. husks and all in some places; in others, the muck is reserved after the first pressure. The mode adopted in the use of the little press, which is directed rather to make a little choice than a large quantity of a middling class of wine, is as follows:—Planks are laid upon the bottom of the press, which is uneven, so that the must may run into one channel, and thence into a cask placed below the level of the floor of the press. The grapes are carefully piled on the *maye* or planks at the bottom of the press, other planks are laid upon the grapes, then several transverse beams of wood, and upon these the press is screwed down. The pressure at first is but slight, that there may be no waste of the must. The pressure is then increased until the utmost force of the screw is exerted, and the muck becomes as hard as a stone. The press is afterwards relaxed, the edges of the hardened mass cut square with an instrument for that purpose; and the cuttings being heaped upon the top, the screw is again applied, and the wine thus produced is called, *wine of the first cutting*. This pressing and cutting are repeated more than once. Finally, the muck is steeped in water, and again pressed, when a small wine is the produce, given to the laborers, called in France, *piquette*, and in Spain, *agua pié*.

The wine-press, an instrument as old as the days of the Israelitish lawgiver, is made in various modes in the same country. In Spain at this day presses are clumsy troughs, about eight feet square and a dozen inches deep, with a wooden screw in the centre. Into such a trough, in Andalusia, the grapes are carelessly flung, with a sprinkling of powdered gypsum in making white wine, to saturate the malic acid. The must is received in jars from holes in the trough, and carried thence to the butts. A bar or lever, of about five feet long, is used for turning the screw. The wine-press used in France for the hermitage wine, is a trough seven feet square, having an iron screw of vast power in the centre. This is turned by a wheel having projecting spokes for the workmen to pull it round. There is a stage round the press for the workmen to

stand upon. The grapes are built up in the trough as high as the screw will admit. The must flows from spouts in the sides, at the bottom of the trough. Wine of the first cutting is then taken. This press will make at once forty casks of wine, of fifty gallons each. The murk is generally distilled. In Burgundy, the

trodden, bruised, and evolving these colors before pressing, it becomes fixed by the heat of the fermentation. In some wines there is apt to be an astringency from the tannin in the stalks, attributable to the desire to preserve the tint; the stalks being acted upon by the heat of the wines, as well as the color in the skins

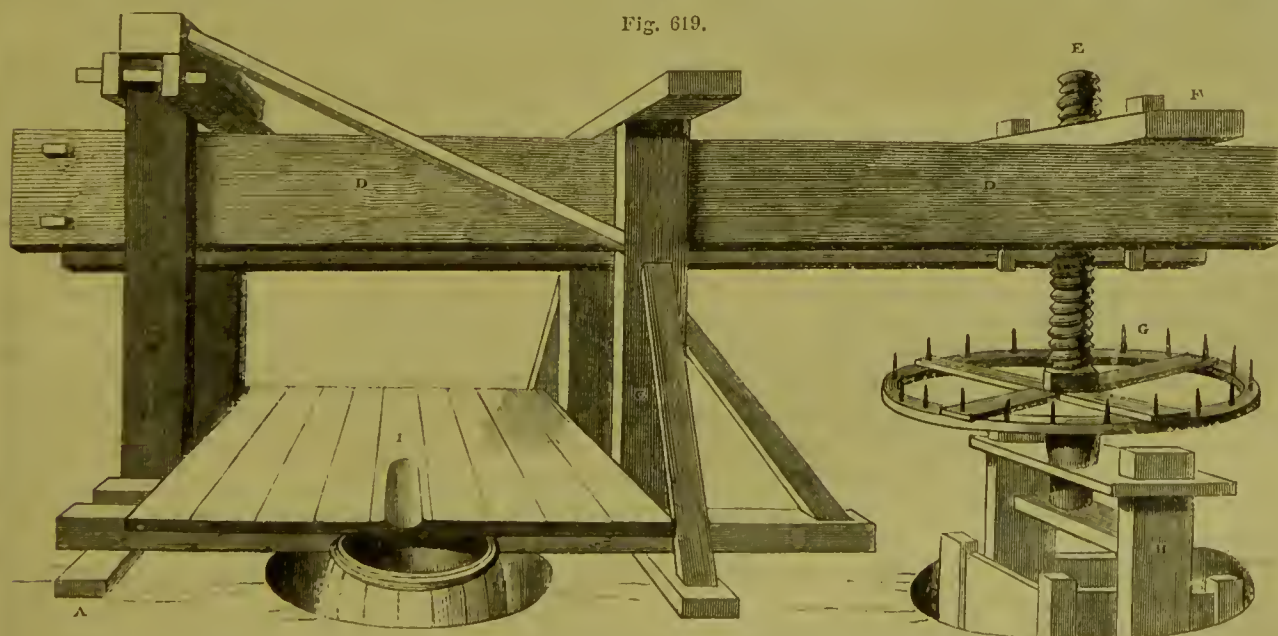
Fig 618.



trough or place for the grapes is twelve feet square, having a lever worked by a wooden screw. There is the *Bascule*, a large press requiring a dozen men to work it. The *Pressoir à étiquet*, moved by levers, or a horizontal wheel worked by four men; and the *Pressoir à coffre*, single and double. One in a vineyard in the Saone and Loire acts by percussion. This press is novel, and is the ingenious invention of M. RÉVEILLON. The press before spoken of as used for making a small quantity of choice wine, in use in France, almost universally, though now somewhat improved, is here represented. In making white wine with red grapes, the want of care in the

carriage of the fruit to the press, and the previous pressing, will sometimes cause the wine to assume a tinge of red, which, though slight, is very perceptible, and hence the epithet of *Partridge-eye* has been applied to it. Of course the quality of the wine is in no way altered by this circumstance. There is but one species of grape, the tintilla, which has a colored pulp. The grapes for the red wines thrown into the vat after being

Fig. 619.



which the rope F runs; E, the cask to receive the must; G, the capstan that turns the wheel and its screw.

The great press, which will make from twenty to thirty barrels of wine in four or five hours, was, in the last century, constructed in the following mode—Fig. 619—and is the most common of the older kind. A A, the base and supporters; C C, the checks; D D, great

beams of timber, sometimes four or six in number; E, the screw; F, the nut; G, the wheel turned by five or six men, holding the upright shaft; H, the cage, a square of timber lined with masonry, ten feet long and four and a half square on each side; I, the *meye* or platform on which the grapes are placed, as in the small press, with blocks and planks over them; L, a

grooved channel by which the wine runs into the vat *K*. The cage will rise or sink into the pit; it is here shown ascending, and is in weight a couple of tons. Suspended at the end of the lever by means of its conjunction with the screw, it possesses immense power, increased according to the length of the lever, and thus it rapidly effects its object.

In some parts of the East the grapes are not pressed at all, but are beaten with wooden mallets on an inclined plane of marble, with a gutter at the bottom, which conveys the must into the cask or other receptacle.

On the sublimation of wines by the alembic, now the *still*, to which in recent times the term of distillation is applied, alcohol is separated. The name of this substance is derived from *al el*, more commonly *al*, the mark of the dative case in the Arabic language, joined to the word *colholmo*—in Spanish shortened to *colmo*—to *rise to the top* of anything; the invention having been brought into Spain by the Arabs.

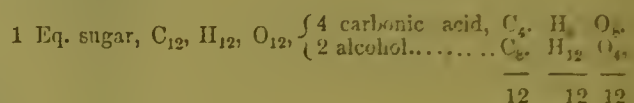
Hence, too, the word *alembic*—*alambique*. The meaning of the original name was retained in the verb to *sublimate*, *sublime*, or *raise up*, to the head of the chemical vessel or retort. Whether this substance was first sublimated or distilled from the must of the grape, or being of eastern origin, from the fruit of the date, or what other fruit, is uncertain; but in wine it is an important natural constituent. Distilled from the grape, it exhibits a superiority over that from every other substance, existing as it does in a variety of vegetal productions. The mode in which alcohol is formed or evolved by the natural process in the fermentation of the must of the grape, it is necessary to explain; its disengagement from other substances by the still having been already detailed under ALCOHOL.

The preparations for fermenting the must by which alcohol is formed, and the process of wine-making completed, are made with great care on the eve of the vintage. In France where the art is most perfect from superior science, the vats are in some places rubbed with over-ripe Portugal quinces; over those of stone elsewhere, a thin coating of whitewash is passed, to saturate the malic acid in the must. Instead of lime, the wooden vats are by some washed with warm water, and afterwards a little brandy is passed over the staves, while others rub them with decoctions of aromatic plants, salt water, or boiling must. These methods are all beneficial, except the use of the lime, which, without great care and judgment, is apt to detach itself and communicate a bad taste to the must, which is deposited in the vat at once from the receptacles at the press, with or without the murk according to the views of the maker.

The whole of the must being in the vat, the fermentation is the next and most important part of the process. It is divided into two stages; the first rapid, sensible, and tumultuous; the second slow, and of considerable duration. The second is often denominated insensible, though sometimes the escape of the carbonic gas is perceptible to the ear in close-covered vessels. The first demands the access of air to proceed promptly through its regular course, which, although rapid, has always a slight progression to the end

of the operation, which is at once discoverable by its being no longer turbid, and by the subsidence or depression of the head or *chapeau*—as the French denominate the scum, skins, and other substances, which float and form a crust upon the surface of the must, or rather of the wine, into which it has now become changed by the fermentative process—and the conversion of the sugar or glucose into alcohol. The reader will find the particulars of glucose described under STARCH and SUGAR, page 606.

One equivalent of anhydrous grape sugar is resolvable into four of carbonic acid and two of alcohol, whence this deduction:—



Sugar of starch and sugar of milk may be converted into sugar of grapes. In the sugar of the cane, and in that of grapes, oxygen and hydrogen are found in the same proportions as water. Grape-sugar, found also in honey and in most fruits, is the slowest of all sugars to undergo fermentation, during which the sugar is resolved as above into alcohol and carbonic acid by the presence, in only a slight degree, of a substance tending to set it in action. This substance results from the nitrogenous constituents of the grape-juice, and is named *diastase*. In making all natural wines, this substance found in the must comes into action spontaneously. Yeast is the product of decomposed gluten. This yeast added to a solution of pure sugar disappears; but when mixed with juices which contain gluten as well as sugar, it is reproduced by the decomposition of the sugar. Gluten is present in the wine-must undecomposed; decomposed in the state of yeast, it would ruin the flavor of the wine, and should never be used to ferment either grape or domestic wines.

The immediate presence of the fermenting agent at once causes chemical decomposition. Oxygen and hydrogen exist in grape-sugar in the same proportion as they are found in water. Carbonic gas is given out; and in consequence alcohol is formed from the sugar, while water is decomposed during the putrefaction of the gluten. A temperature of 65° is most congenial to vinous fermentation, during which the heat increases. At 60° the fermentation is perceptible, but exceedingly languid. There are instances where it has been known to rise as high as 97° or 98°. Thus the fermentation in warm weather is found to be considerably accelerated. When the weather is cold, boiling must has sometimes been thrown into the vat, and red hot-iron bars have been plunged into the must with the same object.

Fermentation in a very small active mass will communicate the principle to a large quantity at rest. The magnitude of the volume submitted to the operation shows, too, that large quantities proceed more satisfactorily than small, though, in the latter case, the alcoholic strength and aroma are better preserved. After the lowering or fall of the crust or head, the sign of the first fermentation being over, the must is covered up from the air; no more opening being left than is sufficient to suffer the carbonic gas to make its escape.

But there are other substances formed in wine besides those already mentioned—some of which amount to little more than perceptible traces, and these are not found in all wines. Their quantity and even presence will depend upon the nature of the soil in which the vine was grown which produced them, and the cold or heat of the season; for in cold summers the fruit is acid. Starch, gum, albumen, gluten, extractive or coloring matter, bitartrate of potassa, malic, tannic, gallic, and a little citric acid, traces of tartrate of lime, of alumina, and potassa, sulphate of potassa, chlorides of sodium and of potassium, and in some, perhaps traceable in all wines, there are racemates and paratartrates. Racemic or paratartronic acid was discovered by M. KESTNER, and mistaken by him for oxalic acid. It is a modification of tartaric acid, and distinct in its nature. It was first thought to be peculiar to the grapes of the Vosges, and was called *acide de Vosges*. This acid is obtained from a solution, containing as well tartaric acid. The crystals are an oblique prism, with a rhomboid base; those of tartaric acid have a rectangular base. Its formula, as given by GREGORY, is $2\text{HO}, \text{C}_8\text{H}_6\text{O}_{12}$.

There is also an odorous principle called oil of wine, which is sweet, quite neutral, and is formed during fermentation, and obtainable from alcohol by pouring two and a half parts of sulphuric acid on one part of anhydrous alcohol. It boils at 536° , and has a specific weight of 1.133. It has a flavor somewhat resembling peppermint, and imparts a vinous smell to the wine newly formed. The salts procured from this oil are identical with the sulphoviuates procured from sulphuric acid and alcohol. There is also a lighter species of oil of wine, specific gravity = 0.917 to 0.920, resembling olive oil. It is composed of $\text{C}_{16}\text{H}_{15}$, or very nearly the proportions of olefiant gas.

Climate makes an important difference in the component parts of the wine-must, as well in the acid as in the sugar dissolved. Hot climates produce a must rich in sugar; but this difference does not appear to affect the extent of the nitrogenous matter in the must, for it seems to be all expended in some wines before the sugar is converted into alcohol; and a part remaining undecomposed, it produces the thick sweet wines of the South. In colder regions the nitrogenous matter and sugar being alike expended, and the wine as it were balanced in regard to these principles, as in some German wines, dry long-enduring wines are produced. When the gluten is in excess, the wine, not preservable with facility, is soon converted into acetic acid if great care be not taken. It absorbs oxygen, and the oxidation is communicated to the alcohol. This oxidation may be prevented, and the conversion into acetic acid arrested, by the addition of a small quantity of sulphuric acid. Fermentation has been ascribed to the growth of fungi and infusoria; but much more evidence must be given before this can be received as a fact.

To return to practical vinification—the method of treating the produce of the vine in fermentation differs with the climate, season, nature of the fruit, temperature of the vineyard, soil, mode of culture and fancy of the proprietor, who is often guided by local custom. In some places the wine is not suffered to remain in the

vat more than from thirty-six to forty hours. Near Lyons in France, it remains six or eight days, and in general from ten to twelve. In the South-west of France, it remains from twenty-five to forty; and at Narbonne, it is carried up to seventy days. When the farmer is asked how, the fermentation being over and the wine at the temperature of the atmosphere, he suffers it to remain still in contact with the stalks and stems to clear itself in the vat; he replies, It is the custom, and, if warned again of acidity through the breakage of the scum or crust, he answers he only acts according to usage—it should be *ignorance*. It is true the crust is almost always compact; but it is a hazard unless the saccharine principle be abundant, and the albuminous matter all taken up.

Vinous fermentation in general takes place under the free admission of air. An attempt was made by a Madame GERVAIS of Montpellier at the close of the last century, to introduce fermentation in close vessels. The idea was not new. M. DE LA PLOMBANIE, M. PORTA, a Neapolitan, and the German chemist, BECKER, at the commencement of the seventeenth century, had recommended the same process. But the admission of the atmospheric air is indispensable to the operation. A considerable noise was made about the invention, which, it was supposed, would preserve the aroma, and prevent the escape of alcohol. M. DELAVEAU instituted some experiments with great care under a fermentation for nineteen days, when it was found that the return from the vat had the most agreeable flavor; that the wine distilled afforded a spirit only equal to that fermented the usual way; the latter if anything yielding the largest quantity of alcohol. The vat with the invention gave sixteen and a half alcohol at a temperature of $80^\circ.5$; the vat with a simple cover, generally used in the South, sixteen and three-eighths; and that not covered at all, sixteen and an eighth. It was thought that the color of the red wines was somewhat deepened by the invention; but neither the aroma nor the vinosity was increased, nor was the invention considered of moment, so as to come into general adoption. Long experience had proved the efficacy of the old mode, and chemistry could find no ground to impugn it in a scientific sense. The strength of the wine, besides that which may be denominated alcohol, or rather its endurance, is in some degree due to the stems and the tannin it contains; but though used in port and some similar second-class red wines, they are excluded from the delicate red wines of France, though adopted in some of the white, while they are also excluded from the Rhine wines. In Spain the wine, having in Andalusia a great enduring power, is left to ferment in the butts, into which it is taken in the *mosto* or must state. The bungs are left open, and the wine and froth thrown up in the fermentation are poured back into the barrel *to feed* the wine, as they phrase it. This causes a renewal of the fermentation at every atmospherical change, and even on any accidental motion of the cask. In the month of March after the vintage, for the first time, the wine is racked. The advantage of large vats has made no way with the Spaniards. It might be best, *quien sabe*, but he keeps to the old track. The delicate and choice French

wines would be ruined by such a mode of conducting the fermentative process.

On the Rhine the fermentation, after the must is ready made from picked fruit, the stalks put aside, and the different pressings set apart, takes place in casks, to preserve the aroma. The wine is then repeatedly racked, and placed in tuns holding about eight hogsheads and a half, where it remains for many years to acquire perfection. Some of the older tuns, in which the wine no doubt mellows best, are those locally denominated *fuders*, and will contain three hundred and fifty tuns. The celebrated tun of HEIDELBERG has long been renowned. It is thirty-one feet long by twenty-one high, and holds one hundred and fifty fuders, or six hundred hogsheads. It was built at Heidelberg in 1663, as a successor to one which held only a hundred and thirty-two. There was once a larger tun at Dresden, shown in Fig. 620, which held three thousand seven hundred and nine hogsheads.

Fig. 620.



It will be interesting to the reader to know the strength of the must at different periods. The specific gravity of the Pedro Ximenes must at San Lucar, after two days' exposure to the sun in September, was 1.092. At Paxarete in October, its must, after four days' exposure, was 1.121. The must of the Mantuo-Castillan grape at San Lucar in September was 1.069. The black mollat grape at San Lucar gave a must in the middle of September of 1.064; and at Paxarete, the last day of the same month, 1.089. At Chipiona, in the middle of September, the muscatel called gordo-blanco, a large white variety, after three days' exposure to the sun, gave 1.089; at the end of the month 1.096; and in October a specific gravity of 1.114. At San Lucar, in the middle of September, the white Temprana grape gave about 1.075; but, on three days' exposure to the sun, the specific gravity was 1.114. This last grape at San Lucar is cultivated to the extent of nineteen-twentieths of the vine lands. In the Paxarete, Ximenes, Muscat, and Tintilla wines, it enters largely.

In Hungary are made the celebrated rich liqueur wines *Essences*, *Ausbruchs*, and *Maslas*, *vins cuits*, and wines suppressed in fermentation mingled with

other substances, and so long noted for their excellence; the grapes are carried in sacks, for the making, as those of Szannorodny, for example. They are treated in fermentation in the ordinary manner. The fruit or the essence, already obtained without pressure, and over-ripe, is carefully picked upon a large table, called a sorting-table, and placed in a cool vessel covered over. It is then put into a large vat, where men with cleanly washed feet, under a superintendent, tread them into a paste. This grape paste is then placed in a second vat, and covered over. New must of the common wine of the country is then poured upon it, the quantity of which used determines the quality of the wine, or wine *de liqueur*, according to the owner's pleasure. Sometimes two measures, or four, five, or six of the essence are added to ten of the common wine. The proportion of six to ten is rarely exceeded. The wine and paste are then mixed, and left for a couple of days, or for three, if the temperature be low, stirring the mass frequently.

This thick must is then conveyed to the press, a slight pressure producing the richest kind; it is next conveyed into a cask, and thus becomes the celebrated Tokay Ausbruch, or flowing syrup. It is skimmed while fermenting, and strained into casks. It has a fine aroma, but never becomes very bright. It is soft and oily on the palate. There are two species, one containing generally sixty-one parts of essence, and eighty-five of wine; and the other called *maslas*, having sixty-one parts of essence to a hundred and sixty-nine of wine. The best sells for twelve pounds sterling the dozen. The fermenting and purifying proceed together. That of 1811 was celebrated, the fermentation having been perfect. There is besides a great variety of wine in Hungary, but all of a peculiar character.

The greatest care in manipulation, and the most scientific methods in the treatment of wine, have been tried in France, and the result has been the production of the finest wines in the world. The removal of the wine from the vat to the cask is there as carefully regarded as the work of fermentation. The casks are all made ready at the same time as the vats. If the wood of which they are made is new, they will not fail to communicate an astringency and bitterness to the wine. To prevent this, the casks are repeatedly washed with cold water, and then with hot, in which peach leaves and salt are infused. They are repeatedly shaken while the fluid is hot, and then are left so that the wood may absorb them, and they may penetrate into the pores of the timber. The casks are now emptied, and boiling hot must, to the extent of two or three quarts, is introduced. The bungs are put in, the casks shaken, and then left to cool. Some use only hot wine in place of the above substances. If the casks are old, they scrape off the tartar that lines the staves, and wash them with hot water and must, or wine. If they have contracted an ill smell, or show the least mark of decay, they are burned at once, because, in

spite of all that can be done, sooner or later the bad effects will appear. Casks should be sulphured, if the least suspicion attach to them, by the introduction of a match at the bung. Such casks are generally made of oak staves, but some prefer beech. They bear different names in different parts of France, as *barrique* at Bordeaux, *botts* at Lyons, *tun*, and *pipe, et cetera*, in other places. When large, they are called *muids*, and very large ones *foudres*. Some have proposed vases of clay varnished, but they are considered porous, and cannot be easily conveyed from place to place.

The wine being fermented, the duration of the fermentation, depending upon the state of the temperature, the amount of sugar and similar things, to be decided upon observation and according to the season, the wine is drawn off into the cask. Some of the finest Burgundies, called wines *de primeur*, only remain in the vat from six to ten hours. The rest in the vat is only important on account of the color. If the skins were sufficiently broken, so that the coloring principle stands in no need of the action caused by the tumultuous fermentation to bring it out, the fermentation with the fruit and its grains being often more mischievous than useful, it is omitted. If the skins are sufficiently bruised and torn, when the fruit is trodden, to give out all the coloring matter, it is not considered wise to suffer the must to enter the vat after pressing.

The drawing off the wine into the cask at the exact moment is a point of great importance. The crust or chapeau having fallen, and active fermentation ceased to the eye, all being perfectly quiet, the examination with a wine glass, the taste, color, and odor, except tested by experience, are often fallacious. Taste and smell are so different in individuals that there is much uncertainty upon the time when it is best to operate. The heat generated in fermentation depends mainly upon the quantity of glucose or grape sugar which has entered into the spirituous state. No fixed rule exists. It is frequently found that the maximum of heat is attained after twenty-one hours of fermentation in one case, and in another after ten, while the wine is not really perfected perhaps for twenty hours longer, so that the thermometer is no reliable guide as to the vinification. Something to determine the fact of the vinification mechanically, was long considered a desideratum by the French producers. There were the differences of climate, soil, and species of fruit to be considered. An attempt was made to ascertain this point by means of a vertical rod, marked with a scale to show the elevation and depression of the fluid. It was placed in the middle of the vat to indicate the depression of the must after its previous repulsion by the fluid, and that the time thus indicated should be that of drawing off the wine from the vat. This was found to be correct in seasons when the sugar was abundant, and then the moment of the retrogradation of the must was the best for emptying the vat. In wet seasons, on the other hand, the indicator did not seem to answer, but the inventor had little doubt of success in establishing a scale to indicate the time sought in different seasons when the temperature varied; but he was unable to carry out his experiments beyond three seasons, having been compelled to become an exile.

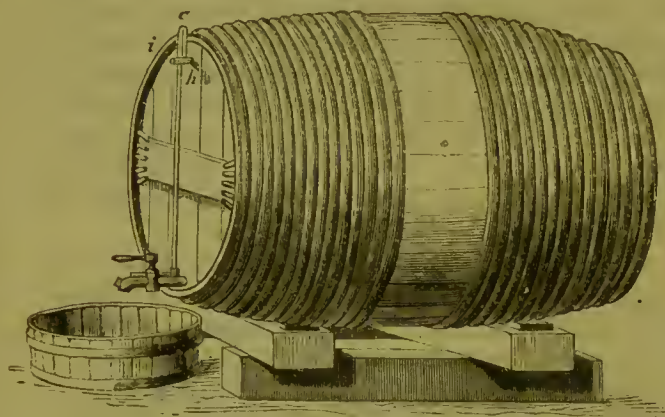
In drawing off the vat it is necessary, before commencing, to take away with great care, by the use of a wooden shovel, that part of the head or crust which, having contracted acidity by exposure to the air, if it broke and became mingled with the must beneath would spoil the whole mass. The must drawn off, the murk remaining in the vat is pressed for the wine called that *of the press*, which is equal in quality to that which has been drawn from the vat without pressure. The wines thus made are called that of the first, second, and third vatting, as before stated. The first taken is the most spirituous, and the last the harshest, sharpest, and deepest-colored. The second pressing holds a middle quality. The residue of the murk is used for the manufacture of verdigris, for the food of cattle, for vine-dressing, or for nourishing pigeons, which greedily devour it. These later wines of the press are sometimes mingled with that of the vat, an indefensible practice, because the wine from the vat will often by such a mixture lose its own peculiar delicacy.

The wine being in cask is, in the pure wine countries, directly placed in the cellar. The cellars vary in different countries. In Spain those of the Xeres district are of great size, to the extent of three hundred English feet long by above two hundred broad. Four thousand casks of wine are arranged in similar cellars in tiers, and are called *soleras*. The wines of different seasons are mingled in these, so that one will contain some of each vintage for thirty seasons. The wine is fermented in the butts, the bung-holes being left open without endangering the wine; nor is the cellar temperature much regarded, such is the firmness of the wine. In Valladolid the cellars are deep in the earth, like mines, with huts over them. In France the cellar is an object of peculiar care, the exquisitely delicate wines of the first-class in that country demanding great attention as to safe-keeping in their highest and most perfect state. The best and favorite cellars are held to be such as are situated under uninhabited buildings, as is observable in the places most noted for the culture of the vine, having a Northern exposure, and fifty or sixty feet deep, according to the dryness or the humidity of the soil. A uniform degree of moderate humidity is best. A cellar too damp causes the decay of the barrel staves, or covers them with a mouldiness which communicates a bad taste to the wine. If a cellar be too dry it makes the staves of the casks shrink, and the wine is wasted by leakage. The air should be admitted only by small openings, facing the North, made near the roof or vault, and susceptible of being closed when the weather is too hot or too cold. The vault or roof should be as solid and thick as possible, in order that no external concussions should be communicated to the wine. The soil above the vaulted roof should be united and well beaten down, and that part designed to receive the bottled wine should be covered with sand or fine fresh-water gravel.

The casks should be placed in a position perfectly horizontal, upon wooden beams six or seven inches square, supported by others transverse. Wedges should be forced under the casks on each side to keep them steady, and neither the casks nor their supports should

touch the wall of the cellar. If the casks are not set perfectly level, the wine lees will collect in the back part and prevent the wine flowing clear out of the cask the usual way. If the front be too much raised, the lees will come to it when the cask is elevated behind, in order to draw off the last of the wine, and thus stop the passage. The lees should settle in the belly or hollow of the staves, which will take place when the casks are kept perfectly horizontal with wedges, as shown in Fig. 621. Attached to the cask here given is

Fig. 621.



an air tube, to illustrate the mode adopted in some parts of France to prevent the admission of air over the wine, so apt to cause acidity.

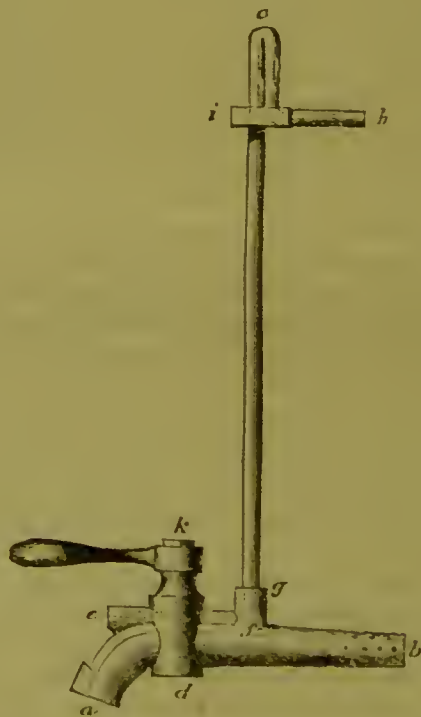
The tube or canal, *abc*, is of the common form, except that the bottom of the tap at *d* is pierced with two apertures, of which the lower serves for the passage of the liquor, and the other corresponds with tube *efgch*, by which air is introduced into the tube to replace the liquid drawn out. The result is that it suffices to turn the tap, *k*, to cause the liquid to run; and to shut it, that all communication with the exterior air shall be cut off. It is evident that when the tap is turned the wine will run out, and that the exterior air will replace that wanting by the tube *efgch*, and that on shutting, *k*, the pressure of the air will cease with the running of the wine. The tube is carried higher than is necessary, that the wine may not enter the tube at *h*, and may have the least possible distance to the surface of the wine, and thus prevent agitation. The tube at *h*, and the tap at *b*, both enter the cask. When the cask is to be all drawn off at once, of course such an application is superfluous, but it is invaluable where small quantities are taken in draft.

No garden stuff, green wood, flowers, fruits, or similar substances must be permitted in any cellar in which wine is kept, because the gas disengaged from them promotes accekeney. The wine being deposited in the cellar, the insensible fermentation commences but too sensibly if that in the vat was imperfect. Carbonic acid gas still makes its escape, augmenting the volume of the wine, and forcing itself out at the bung in froth or scum. Hence it is necessary to take care that the casks are not quite filled when they leave the vat. At least two inches' space is left, and the bung driven home to prevent the slightest entrance of the atmospheric air. A gimlet hole is made on the upper side

of the cask, and stopped with a peg or *fauces*, in order to let the carbonic gas escape. Some wine-makers place in the bung-hole a linen cloth, filled or covered with sand or vine leaves pressed down with a tile.

When this fermentation ceases, and the wine has sunk down, the cask must be filled up and hermetically closed with linen round the bung. The operation of filling up by the bung is denominated *ullage*. In some places ullage is performed every day for the first month, every five days for the second, and every eight until the wine is racked. The celebrated Hermitage wine is thus treated. At Bordeaux ullage is performed on the eighth day—filling up exactly every ten days during the first month, and then once a month to the time of racking. In other places, if the cellars are dry, twice in two months; if humid, every three months. Ullage is performed in fine weather with wine fully equal in quality to that in the cask. The cellars are to be visited daily to guard against accidents, such as a leak in a stave from a wormhole, injury from commotion in carriage, mouldiness of the staves if the cellar be too damp, or shrinking of the staves or heads in those which are too dry. The wine from time to time is tasted, to ascertain its state and remedy any perceptible mischief. When ullage is neglected, a white mouldiness, called the *Flower*, is observed on the surface of the wine—a certain forerunner of acetous degeneration. The air is at once forced out, the nozzle of a bellows being introduced for that purpose, and then it is agi-

Fig. 622.



tated. A sulphur match is introduced, and the bung inserted. The cask is struck from below, to raise any concealed air bubbles to the surface, and to carry all the mouldiness possible to the bung-hole, which is filled so as to make the wine run over, and these efforts are continued until no vestige of the Flower appears. The wine in the cellar is observed to work much when the vine commences to bud, and when the fruit ripens,

which BUFFON attributes to the changes in the juice of the vine. FABBRONI and other authorities have stated that this phenomenon is only observable when the particles of the wine have not been separated by a sufficient quantity of alcohol—in other words, when the glucose was not equal to the subjugation of the gluten, and the other constituents were not in due proportion. This fermentation is prevented by the use of sulphuric acid, sulphate of lime, mercurial oxides, additional alcohol, camphor, ice, and water at the boiling point. When the wine is still, it is perfected, and only deposits its lees, consisting of portions of the pulp of the fruit, of the coloring matter, and of the tartar, which last is found crystallized on the interior of the staves of the cask.

The next process is that of racking, undertaken to clear the wine of the substances which tend, by mixing anew with the wine, to form a fermentation. It is an operation not generally performed at a stated time. In some places it is done in December, after the vintage, when the wine is required to be moved; if not, it is done annually, generally in the months of February or March. In some countries this operation is performed twice the first year, in spring and at the end of September; in others, at the end of December and middle of May—the first during a sharp frost. Much, however, depends upon the quality of the wine. Generous wines may rest upon the lees three or four months, and be only racked once in two years, but in general they are separated from their lees before the first equinox of the spring succeeding the vintage. There are times when, on the other hand, in lieu of racking, it becomes necessary to recombine the lees with the wine, in order to establish a fermentation which may ameliorate them and promote their maturity. This operation being of importance, it is necessary to describe. The smallest inadvertence will produce, in conducting it, the acetic action, the tendency to which, the moment it is perceived, must be met by racking at once, and moving it to the coldest place possible, and before racking it must be fined. The weather most proper is that which is dry and clear.

The wine is drawn off carefully that it be not disturbed, and when the cask is stouped for the last of the liquor, it must be done with great care and judgment by hands accustomed to the operation. The Beanne wines in France are generally racked by the introduction of an instrument into the cask well calculated to draw off the fluid without disturbance, and these wines are always remarkably fine. At Condrieu on the Rhone, the wine is racked eight days after it is made, and before the end of the month it is fined, then racked anew, sometimes twice or thrice at an interval of fifteen or twenty days, in order to procure the limpidity so desirable. Wines not cleared sufficiently by racking are fined, the substances used for the purpose being isinglass and whites of eggs. The isinglass is cut up and steeped in a little wine, until it becomes viscid and softened. It is then thrown into the cask. The wine is afterwards strongly agitated. The quantity of finings used is about five drachms to every five or six hundred litres or quarts of wine. The whites of eggs, preferred in some places, are well beaten up in a little wine, poured into the cask, and left to rest for ten or fifteen

days, when the wine is racked during the first Northerly wind. From six to ten fresh eggs are used for every twenty-two gallons imperial. Various substances have been applied for the purpose, as gum-arabic, hartshorn, calcined flint, rice, milk, and starch, but none produce the desired effect so promptly as isinglass or the white of the egg. Ordinary wines lose their acidity by fining, and the finer classes increase their brilliancy and clearness.

Wine is sulphured at times, in other words, impregnated with sulphurous gas, by burning sulphur matches over it. These consist of a roll of linen or cotton an inch and a half broad, and six or seven long, dipped in melted sulphur, to which powdered leaves of aromatic plants are sometimes added. Those made at Strasbourg are noted. The match is suspended from the bung-hole by a wire, and being lighted, the bung is closed. The air within dilates and escapes through the smallest opening. The operation contributes greatly to the preservation of the wine, though some say it injures the color of red wines. Those who object to it throw a little brandy into the cask, to which they set fire with a bit of lighted string, and while it is burning close up the bung, leaving only just air enough to keep up combustion. In other cases a wine is made; the fermentation is arrested, and the must placed in a cask until it is a quarter filled, and a number of sulphur matches are burned over it. The cask is then closed and strongly agitated, until no gas escapes on opening the bung. More must is then added, and the agitation repeated, until the cask is full. This must never ferments, has a sweet taste, smells strongly of sulphur, and when a certain quantity of alcohol—of the strength *trois-six*—is added, a wine named *wine of Calabria* is the product, employed principally to give strength and sweetness to wines deficient in those qualities.

MULDER states that wine, stored in wooden casks, loses water, whether mixed with alcohol or not. But if evaporation affects the contents of the cask, the loss must be repaired, otherwise the action of the air would turn the wine acerb, and convert the alcohol into acetic acid. It is chiefly water which is evaporated, and its loss is made up by adding wine. All the constituents of wine, with the exception of water, are hereby increased, and the wine becomes not only stronger, but better flavored. The vinous components being more concentrated, are better able to act chemically upon each other, and this, *per se*, would account for the improvement of the wine. Here one has a general statement of the causes upon which the difference between new wine and that which has been stored in casks mainly depends. But the change is carried still further. The concentration of the wine, or rather the diminution of water, which is continually replaced by wine, causes a constant augmentation of tartaric acid in the wine. Wines which are poor in sugar may easily become too sour, and all wines cannot, therefore, undergo this process. The quantity of tartar in the wine is not increased; for, being insoluble in alcohol, the continual increase of alcohol precipitates it. That which is augmented is tartaric acid, which is soluble in alcohol, and insoluble in cream of tartar.

Madeira, and such like wines, are sent to warm countries to improve. MULDER had Madeira which had been seven times in cask to the East Indies and back, and truly, says he, *such nectar was unknown to the gods of the ancients*. The drier the atmosphere is which surrounds the casks, the greater will be the evaporation. To avoid this, care must be taken to prevent draughts, and to keep the air of the wine stores or cellars moist.

Wines remain in wood different periods, according to their qualities, and while thus resting are in a state of improvement. Some repose only three or four years before bottling. Tender, delicate, light wines gain little in the bottle, while strong spirituous ones preserve well in that state, and to a certain point improve. In bottling fine wines the bottles and corks should be new; the smallest defect in the latter determining their rejection. The French dip the corks and the bottle necks in a composition differently colored, to distinguish the wine, and thus shield the external part of the cork and a little of the neck of the bottle with it from the action of the air. This composition is made for three hundred bottles with two pounds nine ounces of rosin, half that quantity of Burgundy pitch, a fourth of yellow wax, and a small quantity of red mastic melted together, so as to form a liquid mass in which the corked necks of the bottles are dipped. In the cellar the bottles should be placed horizontally, to keep the corks always wet. Fine fresh-water gravel or sand is their best bed, and keeps the wine cool, but sea-sand from the salt in it, is pernicious. Sawdust only answers for coarse wines.

Wines of fine quality can only be mixed with others of a like quality to render them more generous, or to have a larger quantity of one particular flavor. It is a robbery or a great abuse to sell wine mixed in any other way for a genuine growth. Wines of Bordeaux are sometimes strengthened with hermitage or wine of Cahors, and are known as Medoc wines; but they are genuine and of good quality. Wines are liable to alteration and to degenerate. Such are loss of color, bitterness, acidity, tasting of old, of the wood, of musk, mouldiness, and what the French call *graise*, milkiness or cloudiness. To amend the last they use pure tartaric acid, taking care that little of the carbonic gas given out shall escape from the cask. This acid is composed of 2HIO , $\text{C}_3\text{H}_4\text{O}_6$ and is found in a good many fruits beside the grape. The acid is mingled with sugar and introduced hot into the cask, which is closed and agitated for five or six minutes. Two days after, the wine is fined in the ordinary way. The carbonic gas is the agent of the cure. Wine is sometimes passed over fresh lees as a remedy for the same disease; and then racking is had recourse to afterwards. Acidity generally attacks wine which wants body. This never amends itself, but proceeds to the acetic state if left alone. Taken at the earliest moment, it is transferred into a cask impregnated with sulphur by the means before described; and different modes are employed for the cure of the mischief. Some dissolve honey, others liquorice, in the wine. Acetate of magnesia, bone gelatin, and similar substances are used; but the best mode of cure is to pass the wine over the relies in

the vat, after the vintage product for the year has been drawn off. Even then it should be drunk early, for it cannot be trusted over another season. Often when the acetic fermentation has already commenced, and there is no resource but to leave it to the vinegar-manufacturer. The bitterness in wine will sometimes become cured by itself when in bottle. It takes place in old wine. If not cured by passing the wine over fresh lees or mingling new with that attacked, it should be reserved for the still. Loss of color generally happens to the deepest-tinctured wines approaching age, arising from a species of fermentation for which recourse is had to purified tartar reduced to a fine powder and mingled. If unsuccessful, it must be mixed with a younger growth. The taste of old and musk—the latter thought to be caused by insects—the deposition of different wines, and the taste of the wood, add to the multifarious cares of the wine-grower and admit of a variety of applications for cures not always successful. There is a wide road here for chemical investigation and experiment yet untrodden, as there is also to determine exactly those constituents which give to certain wines their delicate aroma and flavor. The odor which is peculiar to all wines must, to a certain extent, be ascribed to enanthic ether.—*Vide ALCOHOL*, vol. i., page 105.—The volatile substance existing in wine, which imparts to it, conjointly with enanthic ether, its vinous fragrance, is alcohol. Other beautiful volatile compounds have been detected in wine, but there is much yet to be discovered. To what substance does a fine Sauterne owe its most peculiar but magnificent bouquet? Acetic ether appears in most, perhaps in all, aromatic wines, and is developed in them by time. The adulterators of wine are well acquainted with this fact, and know how to make use of it. Acetic ether is largely sold for this purpose, and added in proportionably small quantities to wines which are not aromatic, to improve their fragrance. Two or three drops are ample for a bottle of wine. The reader is here referred to the article ETHER, vol. i., page 532, for full particulars with regard to the properties, *decolor*, of the delicate ether existing in wine and spirits.

Besides the wines denominated sweet and dry, prepared from the fruit in the mode, and their difference arising from causes already stated, there are prepared wines in which the must is concentrated by evaporating a portion of the aqueous part, a very ancient custom wherever wine of the usual kind is made, called in France *vins cuits*, in Italy *vino cotto*, and in Spain, from the Arabic, *arrope*. The wine is boiled down to a third part, being skimmed of its froth, and sometimes, while boiling, aromatic substances are infused, or else it is used in its unperfumed state for strengthening other wines.

Dry and sweet wines, or wines of *liqueur*, are distinguished principally by the saccharine principle, in sweet wine, not being all converted into alcohol, the glucose surpassing the gluten in proportion, and the change being in consequence only partially effected. Such are the wines of Malaga, Rivesaltes, and Frontignan, and the wines from the rich muscatel grape more especially. Straw wines are also sweet wines, made of grapes for some months suspended upon straw bands

and afterwards pressed and fermented. The produce is about a sixth only of that obtained at the vintage. It has a strong rich flavor of the dried raisin. There is also a wine called *de Grenier* in France, made in nearly the same manner, and a sweet white styled *de Garde*.

Another wine of a very distinct character and of two kinds, one drier than the other, is procured by suppressing the fermentation, in other words, retaining the carbonic gas to a considerable extent. This species comprehends the wines of Champagne and their unworthy imitations, called sparkling Burgundies, Moselles, and others, all managed in the same mode. There is a genuine wine at Arbois of the same kind, or *mousseaux*, as the French term it, made in a mode somewhat different. The crust or chapeau is allowed to rise and settle over the must, as in the common mode of fermentation, so far as that the fermentation is not visible and no further, in order that the wine may be racked off in a clear state, being watched day and night for the period when bubbles of carbonic gas begin to appear on the surface. It is then racked into a vat and remains until a second crust or scum forms, and this is repeated until the wine is perfectly limpid. It is now placed in casks carefully kept filled. The bungs are daily examined in case of starting, that the cask may be filled up immediately. The air is excluded when the fermentation ceases, racked again in January or the following month, and in March fined and bottled. The corks being wired, the wine is deposited in a cellar of the requisite temperature.

To return to the more celebrated wines of Champagne, distinguished as still, creaming, and sparkling wines, or *mousseaux*, *crémans*, and *non-mousseaux*, of which the two last are most in esteem. The best froth very slightly, as Sillery; and the finest, called *vin du roi*, not at all. These wines come from the banks of the Marne and constitute a unique class. They are made for the most part of the blackest grapes, gathered with care, and only the sound fruit used. The grapes are carried to the press in baskets, covered up from the sun, and placed on the press with as little motion as possible. The must is poured into a vat for a term of from six to fifteen hours, that the dregs may be deposited. As soon as ever fermentation appears, the wine is transferred to the cask. The product of the first pressing is set aside as the choicest. The second pressing, or the wine of the *first cutting*, lightly colored and spirituous, partly composes the effervescing wines. The wine of the third pressing is kept for giving strength to the ordinary red wine of the country. This wine is put into bottles in March or April. At Rheims, on the other hand, they bottle the Sillery in January, although at the risk of its imbibing the effervescing quality. It having been thought advantageous to secure champagne of a uniform quality, which it was difficult to do from its being put into small casks; tuns holding twelve thousand litres were a few years ago introduced at Rheims by a German house, and the advantage of their use became evident.

The next step is to procure bottles of great strength, free of air bubbles, of the exact size, and without a flaw. The number required to bottle the effervescing wines in the department of the Marne is enormous; eight hundred

and sixty-six thousand gallons having been bottled in one season in the arrondissement of Epernay alone. In March or April the bottling commences. If done earlier, the breakage would be greater, fifteen per cent. being the ordinary loss. In the fermentation the carbonic gas not being allowed to form sufficiently or fully develop itself in the cask, it is quickly reproduced in the bottle; the saccharine principle renews its progress towards alcohol; and if the latter be sufficient to prevent the decay of the wine, the quality is good. This wine does not effervesce in uniform times. Some kinds will do so in a fortnight; others will be months before the signs appear. One wine will require a change of temperature for the purpose, and must be brought up nearer to the surface of the ground, if the cellar be deep. Another kind will not exhibit itself until the month of August, and a third kind only at the time the owner's patience is almost exhausted, when it will appear unexpectedly. If a wine shows no sign the first year, it is mingled the next year with new wine known to possess the effervescing principle. Nothing is certain; the cellars, their soil and depth, the air-holes, the difference of the place of growth—all seem to have an inexplicable effect upon the operation.

The bottles, carefully cleaned by rinsing and shooting, are placed in the working shop or *atelier*. The barrel-heads are bored, and a small brass pipe with a gauze-strainer, is inserted. The bottles are filled so as to allow about two inches clear space between the cork and the wine. This space diminishes, while the carbonic gas is generating; and the fractured bottles show that the expansion of the fluid has primarily quite filled the void. A workman who fills the bottles passes them on the right hand side to the principal operator, who is seated upon a stool, with a little table before him covered with sheet-lead, and about as high as his knees. He inspects the allotted space between the cork and the wine, regulates it exactly, selects a cork, moistens it, introduces it into the bottle, and strikes it so hard two or three times with a wooden mallet, that an observer wonders it is not broken by the violence of the blows; and yet fracture this way is rare from the attention paid to the management of the bottle at the same moment. This workman then passes the corked bottle to his right, where a third workman, seated precisely in the same manner, crosses the cork with pack-thread, and ties it strongly. He then passes it to a fourth workman who wires the bottle, cuts the wire, and hands it to a youth who places the bottles upright in the form of a parallelogram, so that they can be counted in a moment. The daily labor is calculated at a drawing of from sixteen hundred to seventeen hundred bottles. The best cellars of Epernay are those of M. MOET, and the bottles run in a pile from end to end, six feet high, and are carried down in osier baskets, having in each twenty-five cases for the bottles. Two men carry them by leather belts drawn through the handles of the basket. Slopes are prepared beneath in cement to carry away the wine from the broken bottles in the piles, with reservoirs to collect it. The bottles are placed head to tail on laths, the corks one way the reverse of the other.

The piles are very solid; and any one of the bottles, with the neck to the rear of the pile, can be easily with-

drawn in order to examine its state, and see if the carbonic gas is developed. If not, all must be got into the proper state, cost what it may. When a bottle is drawn from a pile, and kept in a horizontal position, a deposition is generally observable called the *griffe*, or claw, from its branching appearance. Before a bottle breaks, the vacancy below the cork disappears by the expansion of the carbonic acid, which generally occurs in July or August, when commonly from four to ten per cent. of breakage is experienced; too often the mischief reaches from thirty to forty. Sometimes, of the same wine in the same part of the cellar, one pile will remain with the gas undeveloped, while the other shows no sign of effervescence. A current of air will sometimes make the wine effervesce furiously. Thus great expenses are incurred, not only by breakage, but in attempts to excite the carbonic development. The loss by the breakage is often not equal to that of correcting the inertness of the wine, independently of the trouble. If not exceeding ten per cent. in breakage, the maker is satisfied. If it is deemed necessary to take down the pile, the bottles are set upon their bottoms for a longer or shorter time, and this causes a difference in the quality of the wine. At one time it is removed into a deeper cellar; or, lastly, the bottles are uncorked to disengage the gas, and clear the space under the cork. When the carbonic gas is furious in its development, the wine is wasted in large quantities. The wine of the broken bottles becomes scattered among the sound, or fragments remain which contain wine, and become acid and even putrid. The gutters become infected, and in the air of the cellar new principles of fermentation ensue. In August workmen have been obliged, owing to the fragments of glass projected from the piles, to put on wire masks, and entering the cellar to throw cold water over the wine. The breakage ceases in the month of September. In October the piles are *lifted*; the bottles being taken down one by one, putting aside those broken, and placing on their bottoms those in which, on examining the necks, the corks and sealing seem to have moved. Some bottles are found to have lost a portion of their contents, and the loss must be repaired. The deposition, too, must be removed. For this purpose the bottles are placed in an inclined position of about 25°, and are shaken two or three times a day, to detach the sediment, for ten or fifteen days successively. Planks with holes in them receive three or four thousand bottles together, keeping them in the right slope. The workmen then, with considerable dexterity, get all the deposition into the neck of the bottle, near the cork, the wine being perfectly clear. Every bottle is then taken by the bottom, kept carefully reversed, and the wire and twine being broken—the bottle resting on the workman's knees—the cork is dextrously withdrawn, so as to permit the gas to explode, and carry the deposition with it. An index is then introduced into the neck to measure how high the wine should ascend, and the deficiency is made good with wine that has before undergone the operation. The bottle is then a second time corked and wired. If the wine remain long in the cellar afterwards, before it is sold, it is submitted to a second clearance or *degorgement* of a similar kind about a fortnight before it is sent away; the

process to the last being laborious and expensive. These wines do not admit of being mingled with any but those of their own growth, and those genuine are rarely mingled at all. Grey champagne is made by treading the wine slightly before pressing, and recolored by a longer treading; but the latter is generally wine of inferior quality. In good cellars these wines will retain their excellence for twenty, and even as far as thirty years, in the last case imbibing only a slight degree of bitterness. The temperature of the cellars in which the wine is kept, is best at about 55° almost unvaryingly. The receptacles at Epernay are excavations in the calcareous rock, thirty-five feet below the surface of the ground. The creaming and still wines keep the best; those very frothy are liable to change, and are really the least worthy of the class.

The finest red wines in the world are those of Burgundy, in the district called the Côte d'Or. They are produced principally from the grape called the Pineau. From twenty to thirty hours in the vat are sufficient to convert the glucose into alcohol, and then in two or three years they are fit for drinking. If moved in the cask in the least as they deposit, they are apt to spoil. On this account the finer kinds are only removed in bottle, and should be kept with great care. When old they take an amber color. In England the first classes of these wines and their proper management are unknown; the second classes alone being imported as the first, the coarse taste of the English palate in wine preventing the discovery of the difference. The finer wines are all produced in the districts of Nuits and Vosne; of these the Romanée-conti and the Chambertin are among the more celebrated. The white wines of the same district are not so well known or esteemed as the red. In the Mont Rachet wine, a celebrated growth, made near Beaune, occurs one of those extraordinary phenomena in wine which no scientific investigation has succeeded in explaining. Three kinds of wine are made of fruit grown on the same land, so contiguous as only to be separated by a footpath, having the same exposure, the soil appearing the same, as well as the species of vine; yet the last brings only one-third the price of the first. The whole ground is about thirty-seven hectares, of which the most prized is but seven, the next quality eighteen, and the third twelve. The wine of the first fruit sells at twelve hundred francs, the second six hundred, and the third four hundred.

The climate of Italy so congenial to the vine, produces no wines of export much valued, owing to the ill management of the vintage. No attention is paid to sorting the grapes; ripe and unripe are thrown into the vat together. Nicety and even cleanliness are neglected. The grapes are trodden and thrown into a vat, where the must remains fourteen days in a state of continued fermentation until the wine is spoiled. Sometimes the must is left exposed to the air for a month together, and the wine, ill-managed, has no reputation. In Tuscany more attention is paid to the process than in other parts of the country, and very palatable wine is made, but with little improvement in the process. The Montepulchiano is a sweet wine long

noted there. This wine is racked repeatedly for two months after it is made, but the fermentation is often continued until the wine has begun to contract acidity before it is removed into the cask. In Naples they make a sweet wine called *lacryma Christi*, but the process is as careless as in other parts of Italy—in fact there are four or five wines of that name, some pretty good, others execrable. In Sicily the Mazzara wines, and the sweet wines of Syracuse, are made with little care; but English capital and some pains having been bestowed on the Marsala and Etna wines, they are exported to England, according to custom, brandied to excess to save care in their management, or, as the phrase is, to *fortify* them. The Marsala wine, well treated, is sound and good, and made in the fine climate of Sicily with French science, might still be greatly improved.

The Greek islands produce wine of various kinds, but mostly muscadines. In Cyprus the grapes are not suffered to lie too numerously on the stock. They are of a rich purple, with a thin skin. The vintage begins at the end of August. For the celebrated wine of the Commandery, the fruit is placed on covered floors called *punsi*, and spread out with care in a bed of eighteen inches thick, where the grapes remain until the seeds or grains are ready to drop from them. They are then carefully lifted with wooden shovels and carried to rooms paved with marble, or covered with a cement equally compact. These floors are made of a gentle slope. The grapes are bruised with a wooden mallet, and pressed in little presses denominated *patitisi*; the must, which is very thick, flowing into a vessel on the lower side of the floor. This vessel is emptied, when full, into small vases, and in these conveyed into baked earthen vessels with acute bases, like the ancient amphoræ. In these the wine is left forty days to ferment, in some places with the vat covered while in that state. This wine, if taken while in a state of fermentation, causes severe colic pains, to prevent which it is filtered through bags of vine ashes, but when thus treated it never attains the perfection desired. When the fermentation has ceased, the wine is shut up from the air with covers of baked earth, and has already put on a lighter color than before. These vessels are either coated internally with pitch, or varnished the instant they leave the potter's hand. If varnished, the composition consists of a boiling liquid in which turpentine and pitch are mingled with vine ashes, goat's hair, and fine sand; this effectually closes the pores, and never falls off. The art of making these vessels belongs to the remotest antiquity. They hold from twenty to thirty barrels each and in them the lees are deposited, which are called *mana*. When removed, leathern bags are adopted, pitched on the inside, and detrimental to the wine, which does not for many years lose the disagreeable flavor. The cellars, in so hot a climate as Cyprus, are all above the ground; little light is admitted, and the aspect disregarded. This famous wine was named from the Commander of the Knights Templars, to whom the district once belonged. The Commandery wine resembles the Italian wine of Chianti in color. From a red it changes to a yellowish hue the first year, fines itself as it grows old, and in nine or ten years takes nearly the same appearance as the sweet wines

of the South of Europe. The dregs are thick, and supposed to aid the fining. When brought from the country to the town and put into casks, it is always in such as have lees remaining, in which it is left for a year. Whether ullage is attended to or not, it makes no difference in regard to the excellence of the wine, for sometimes a cask is left not three-fourths filled. It is sold at the vineyard by the load of sixteen jars, each containing five Florence bottles. The wine is warranted good by the seller until the August after the vintage. It is generally exported in casks of three hundred and fifty bottles each. Only about ten thousand jars are now produced. When poured into a glass, if good in quality, the particles adhere like oil to the sides. Cold injures it; in a Northern climate it must be placed before a fire. The lees are always treasured up, and are often in color a mixture of black, red, and yellow, though generally like Spanish snuff. Those wines and the muscadines of Cyprus are different. The wines of the Greek islands are mingled with rosin to impart durability, and are very disagreeable to the taste in consequence. The wine of the Crimea, at least that called *kokour*, is fermented coarser than in Cyprus. The vats in many places are only pits dug in the ground, plastered with a composition. The Shiraz wine of Persia is made of trodden grapes, fermented in jars of glazed pottery agitated briskly; it is then bottled for sale.

The wine of Portugal, forced upon the people of England in 1703, by rendering the duty on that wine a third less than on the produce of other countries, drove out many fine wines, of which there was a great variety before, and forced an inferior article upon the public, under the absurd idea that Portugal would take English woollens in return, as if all trades were not an exchange of goods. The effect was to drive all variety in wine out of the country, and make Englishmen take an inferior article. At first the wine came in its natural state, but was afterwards sophisticated and brandied. Efforts were too soon made to control the market by limiting the supply, and rendering the wine nearly of a uniform quality. After the Portugal wine monopoly of 1756 was established, brandy was added, and increased until, in recent times, no less than from twenty to twenty-four gallons per pipe are flung into the wine during and after fermentation. In its natural state this wine is not permitted to come to England. The growth is stunted because the export is limited by a privileged company, which creates an artificial scarcity. The wine is adulterated with a mixture called *geropiga*, two-thirds must, and one-third spirits 20° above proof, with elderberry juice and sweetening matter, and is sanctioned by the English Government, though a gross adulteration, being admitted here as a spirit to carry out a fraud. This medley is used only in preparing wines for England. The pure wine is seldom allowed to be exported, although good and enduring, since by this doctoring there is an equality of class established that defies seasons or bad crops. The grapes are gathered when mature almost to shrivelling. They are from the bastardo, sousao, and alvarellhao vines. The fruit is trodden with the stalks, and remains during the fermentation, which continues about seventy hours, in vats

containing from ten to twenty pipes each, and while fermenting, brandy is added. The wine is racked in February, and sent to the company's or merchant's cellars in Oporto. More brandy is added to the wine intended for exportation, and again in a year, when shipped, more is thrown into a wine having in its natural state, on the average, amply sufficient alcohol to insure endurance with common care. It now carries a strong odor of brandy, and must remain a dozen years until the wine, or rather brandy-wine, is sufficiently subdued in alcohol to be drunk, when it bears little resemblance to the genuine wine, having become dull, and its freshness and aroma having disappeared. The consequence of the delay often is, that while ameliorating the extractive and coloring matter of the original, if not of the elderberry, becomes deposited, the wine tawny, and the flavor without a trace of the real unadulterated article. The perverseness of usage is become in a century so much in harmony, on the part of the consumer, with the merchant's notions of brandy being necessary to preserve a wine with sufficient alcohol by nature, that a genuine and honest port wine would now be regarded as worth little, on the plea of coldness, except to real connoisseurs. At first, in 1730, only about two gallons were added to a pipe. In 1754 the practice was styled *diabolical* of checking the fermentation in this mode of *fretting* in spirit, which it was fondly imagined immediately assimilated with the natural alcohol of the wine. The Portuguese charged the English at Oporto with commencing this base practice, and making wine seem *like liquid fire in the stomach*. It is observed by one authority that, in preparing these wines, it resembled throwing into one large vat all the red wines of a country of different growths, to produce an immense quantity of second-class wine. There are excellent wines thus mismanaged. The Collares port, Bucellas, Lisbon, and other wines made in the customary manner, bespeak that there is no fault except in the management. One wine-grower purchased elderberries a few years ago to the extent of four hundred pounds in a season; and one hundred and twenty pipes of adulterated must have in one year been landed in London from Oporto, to mingle with Portugal red wine in England, and doctor or strengthen what was too weak. Science can discover nothing worthy of record in the manipulation of the Oporto wines.

The vines of Madeira, now nearly destroyed by the *oidium*, or wine disease, were a remarkably fine class. They were planted in a volcanic soil, a mixture of red and yellow tufa, called *saibro* and *pedro molle*. A light clayey earth and volcanic cinders were intermingled. The husbandry was rude; the vines planted in trellises. The vintage took place in September, and the wine of the highest quality, called *pingo*, was that which flowed from the treading alone. The wine was pressed to the fourth pressing in a trough-press, with a lever like that of a cider press. The grapes were sorted and the *mosto*, or must, fermented in pipes. Gypsum was sprinkled on the grapes. The must was agitated during the fermentation, which exceeded forty days in duration. The wine was mellowed in stoves, kept at a temperature of 80° or 90°. A voyage to the East or West Indies was always preferable for

ripening the wine, when it could be accomplished. There was once a very agreeable cordial wine, made in Madeira, by checking the fermentation and adding brandy to the must. The *sercial* is the product of the hock grape, never drunk under seven years old, and then not in perfection. There were once three kinds of malmsey, from as many different kinds of grapes, in these islands. That from the cadel grape was the best. The tinto resembled new Burgundy, but was less harsh; it was drunk under three years old, at which age it lost its color, and took that of old Madeira. It had an agreeable aroma. Wines of Madeira were sometimes ripened by plunging them into a trench of fermenting horse dung. The bottles were corked, and thus the wine attained, in a few months, the maturity of a voyage at sea. This, however, may be doubted; because, at sea, not only a particular temperature, but a considerable agitation is kept up. A pipe of Madeira, attached to the beam of a steam-engine, in the warm engine-house, is said to have produced the effect desired. Madeira is, or rather was, in perfection in twenty years. The vine disease has suddenly ruined this far-famed wine, and the unfortunate people of the island that produced it. A very fine sample of this wine the Editor received from Mr. J. R. HUTTON of Liverpool—a nutty flavor, and yielded 15.69 per cent. of alcohol.

The wines of Spain are quite distinct from those of Portugal, as well as of France. Many of them are superior of their class, and of the white wines in particular; they constitute the largest quantity of any single foreign wine, red or white, entered in England for home consumption. The wines of Spain, except those of Andalusia, in which much British capital is invested, are carelessly made; but their firmness, just alcohol, resistance to what would ruin very delicate growths in the North, arising from a warm and genial climate, prevent their merits from passing unappreciated. The fine red wine of La Mancha, the Val de Penas, was, until recently, carried about only in pitched skins on the backs of mules. The great exports of wine are from Cadiz and Malaga. The sherry is made near the town of Xeres de la Frontera, nine miles from Port St. Mary's, across the harbor of Cadiz. The grapes are left on the tree until they are shrivelled by the sun's heat, and when plucked remain exposed to it some time before they are pressed. The fermentation is generally left to take care of itself, with all the scum it forms; and yet the wine is so fine that very rarely mischief occurs to it. Racked after the vintage, and constantly under the eyes of the agents or principals of foreign houses, resident on the spot, the management is carefully scrutinized. The grapes here are sprinkled with powdered gypsum, once locally termed *gicso* or *jess*. The must ferments in the cask left entirely to itself. It is racked in March. The casks are left open in all temperatures, and sometimes in the open air without ill effect. A good cellar, so named in France or the North, is not thought of moment here. While fermenting, the bungs are so open as to allow the easy escape of the carbonic gas. Ropiness, dreaded elsewhere under such treatment, is very rarely observed. The natural color of the pure wine is pale; the colored are from a

blending with a dark wine called *arropé*, made by boiling down six butts of must to one, keeping the liquid continually stirred and the surface skimmed, avoiding the accident of burning, on which account the process is slowly conducted. When thick enough, the fire is gradually withdrawn, so that the fluid may cool without any injury from chill. It is then mingled in different proportions with the pale wines, thus constituting colored and brown sherry. Nothing foreign is ever mingled with these wines, except a couple of bottles of very good brandy upon their exportation. The sherry, denominated *amontillado*, is a drier wine than the common sherry, and is often the result of accident. To this wine no addition but of its own class can be made without spoiling, not even a glass of brandy. A sample of this pure wine the Editor received from the highly respectable house of Messrs. CHILLINGWORTH and SON of London. It had a superb flavor, and only contained 11.50 per cent. of alcohol—proving it to be a pure wine. Of a hundred butts from the same vineyard, some will be *amontillado* without it being possible to discover the cause. Thus the constituent parts in *amontillado*, if supposed exactly balanced, raised the question, Why should this occur in a small portion only of a larger quantity? When it is made, the grapes are plucked a week or two before those for the other wine, but the treatment is just the same. The wines that pass for sherry in England in taverns, are generally made-up wines, or good mingled with inferior or low wines. Another species of wine which may come under the sherry denomination is that called *Manzanilla*—light, delicate, and straw-colored; it is not always liked at first. It derives its name, some say, from a village near Seville, and as others suppose, from *Manzanilla*, a small apple. Neither surmise is correct. *Manzanilla* is the camomile, and there is something of the taste of that plant in its flavor. It is delicate and will admit of no foreign mixture. The dryness shows that the glucose and vegetal extract are well balanced in its fermentation. It is produced from the *Rustan* grape. The wines of Malaga are of ancient date, and the vines are grown near sugar canes, the only spot in Europe where the latter are found. The *bastardo* grape makes the sweet wine. The must is conveyed from the press, half fermented, to the merchants' stores in sheepskins, and the wines are sent to all parts of the world unbranded, except to England. The mountain wine is made in Malaga, and one species is called wine of pears, because that fruit is steeped in it. There is also a cherry wine, called *quindas*, made there. It is much flavored with the cherries. There are many excellent wines in the interior of Spain, but made unpalatable from bad management in the fermentation, exemplifying the Spanish proverb—*To cry wine and sell vinegar*.

The dry wines of Xeres and Malaga, as well as those of Tenerife, were formerly called *sacks*, and the sweet also. In 1598, in Hakluyt, it is stated by one who resided eight years at Tenerife, that it produced three kinds of wine—Canary, Malvasia, and Verdone, which may all go under the denomination of *sack*. The wine of different ages is mingled in Andalusia, the newest with old of the purest quality.

The wines of Andalusia are rarely sulphured, from

fear of the taste remaining, and on account of English prejudices. Some Englishmen complained of the taste where sulphur had never been used. Here the stalks, and often not even the skins of the grapes, are suffered to ferment in the must. The wines are white, and color is not wanted. In France the stalks are left in the must according to the nature of the season; if fine they remain. In Spain the glucose abounds in the grape; and were it not for the practice of leaving the seum on the wine, and even returning it under the idea of supporting the wine, none would ever become acid. The system of large vats, so friendly to a beneficial fermentation, has not been tried there. Nor is it necessary; for in their present state they enter into the largest consumption in the English market. The better wines of Southern Spain yield nearly a fifth part of alcohol on distillation, and the quality so returned is excellent, and only inferior to the best of France. The *tiutila* wine of Rota is a red of Andalusia, generally taken as a cordial from its extreme richness. In Alicante a wine is made from the same kind of grape, which holds much tannin, precipitating a species of animal gelatin. It is of an orange-red color, rough, and somewhat bitter. In Catalonia the wines are generally good, and of the red species. *Vinaroza* and *Benicarlo* produce good red wines, much of which passes for port in England, either mingled with it or flavored, so as to secure the similitude. This wine is of a wholesome quality. The *malmsey* of Sitges is white. In Arragon, the wine of Carinena is the best. A muscadine named *Fuengaral*, is made near Madrid, and a fine dessert wine at Peralta in Navarre.

The wines of Spain have the ascendancy in England, perhaps from their freedom from acidity, owing in part to their treatment in the vat with gypsum, to which must be added their own natural tendency and strength, as seen on their exposure to the atmosphere under circumstances in which the wines of other countries would run rapidly into the acetous state. Wines which contain much of the gluten, are more susceptible of the acetous fermentation than those in which it is more sparingly dispensed; and the latter is the case with the wines of the Xeres district, in which little or none remains after fermentation, without half the trouble in racking and fining which is bestowed on other wines. There can be no doubt, this refers to the white wines of that part of Spain alone when the spirituous fermentation has ceased. The little brandy added, and often none at all, to the best wines of Xeres, as is evidenced in the beautiful sample of Messrs. CHILLINGWORTH above referred to, shows how well their constituent parts are adapted for preservation, compared with some ports and oftentimes their twenty gallons of artificial brandy. It is only to the meagre wines of the country—mingled with a little of the good, and called *low sherries*—that brandy is added, to render the wine more agreeable to the corrupted taste of the English public, which is thus to be satisfied with brandy and wine in a state of mixture, in place of brandy and water. The intemperate use of pure wine when indulged, is never followed by those disorders so common and fatal in the use of the favorite dull fiery wines of the generality of persons in England, particularly in the class called hepatic affections. Brisk,

lively, natural wine, is totally distinct in its action on the human frame from that of the brandy wines medicated for a perverted taste. The effect of pure wine in excess is transient; of brandied wine it need not be detailed. The Editor is convinced, from investigations and analyses, that there is no more *necessity* to add brandy to port than sulphuric acid to vinegar. If the liquid be well fermented, sound, and good, any addition is pernicious and wicked.

There is no just ground for believing that brandy will prevent acetous fermentation, although the common notion is that it will do so. It is incredible how far custom goes in effecting error, and preventing its correction, often indeed irremediably. A merchant of good sense desired to have sent him, even if smuggled out of Oporto, half a dozen pipes of port-wine without a drop of brandy. His correspondent would only send him one in reply to the order, being certain *that without brandy it would not keep*. The wine came and remained good in the cellar for years till drunk out. The Oporto merchant did not know, that for forty or fifty years after the Northern treaty of 1703, little or no brandy was put into a wine of a very full body, nor that Sir EDWARD BARRY complained in 1773 of these wines becoming too hot. It was not until the end of the last century that they were so fully deluged in artificial spirit—introduced at first under the idea of their preservation, and continued, perhaps increased, by fevered stomachs, which called for deep colored, sweet, and strong; in other words, for more elderberry, sugar, and alcohol.

Brandy in a small quantity will not stop the acetous fermentation in vinegar, for it becomes itself acetified, and makes the vinegar stronger. That one-seventeenth part alcohol should succeed in so doing, as some experimentalists aver, is met by other facts; for acetous fermentation is very easily produced in wine containing an eighth part of alcohol. It is still possible that alcohol added in a sufficient quantity may suspend or retard the fermentation, owing, perhaps, to its not mixing with the natural alcohol of the wine. Chemistry has not yet made this point clear; but it would seem that the general notion of vinous preservation through alcohol, unless in a ruinous quantity, as it is applied in port, sometimes to more than a fifth of its bulk, is very erroneous. The Editor has found port sold in some of the hotels with *thirty-five* per cent. of brandy!

The fact is, that the usage at first, from whatever cause, gave a desire for strong wine in England; and there was the advantage that the growths of bad and good years flung into large vats, and well mingled with braudy, gave a product of that middle-class wine artificially so made, which paid better than a little choice at a high price, and a good deal at a very low figure. It must be observed, too, that in most Northern countries, except France and those yet more to the South, there is a continued craving after alcoholic strength. This has been the case in all ages of the world. The Englishman has his wine medicated until spoiled with brandy; the Persians infuse poppies and similar things for the same end. There is ever a craving for increased stimulants, which, not found in the wine itself, must be added. The Greeks and Romans medicated

their wines, or rather perfumed them with various substances. The holy scriptures have left evidence of this, even in the earliest times of the Jews. The alcohol in wine placed there by nature seems to have its parts separated, and to be rendered comparatively innoxious compared to that added unnaturally; and, in the former case, will not readily intoxicate like alcohol mingled with water, milk, and similar liquids. The Jews had no knowledge of alcohol or the still, and endeavored to render their wines more stimulating by their deterioration, as is done at present another way. They had a general term for fermented liquids of all kinds—*shekhar*; but the words, *strong drink* or *mixed wine* are denounced, meaning wine with spices, and stimulating aromatic drugs. *Johin* or *Yayin*—the *j* is pronounced as *t*—is the term for wine in general; *sobhe* is sometimes used figuratively for the same liquor, and *tirosk* for new wine. But *shekhar* means strong and medicated wine, of which honey was one ingredient, as well as spices and herbs. In the time of AUGUSTUS CÆSAR honey was mingled with his wine, and exposed to the sun, perhaps fermented in it; and as honey contains grape-sugar, it would necessarily strengthen the alcoholic principle, if there remained any gluten, for the emperor could drink no more than a pint of it at a time. Alcohol is formed by nature in every human stomach to a certain extent, according to an eminent chemist, and so far must be congenial to it. The reasonable use of natural wine is often highly advantageous. Discoveries in relation to the combination of alcohol with wine are yet to be made, but it remains certain that it is one of the vinous elementary constituents. Medical men will designate the difference between the effect of wine with its alcohol on the human economy, and the effect of alcohol combined with water. The ebriety produced by champagne in which carbonic gas and alcohol are combined, and that produced by pure claret or chambertin with port and madeira, are obvious to all who move in society where good wines are taken. The effects so lively and airy of the one, with the dull sedative state produced by the last, a blunted quiescent state not easily disturbed, but when disturbed not easily appeasable—indicate different effects from causes, no satisfactory definition of which has yet been obtained.

There has been much dispute regarding the alcoholic strength of wines. There is no reason whatever to dissent from BRANDE'S analysis of a considerable variety, made with great care, and there is little difficulty in making the test correctly enough; but the utility is only comparative, because the particular wine to which the test is applied must be taken for itself alone, according to the nature and produce of the grape for the year of the vintage, and not for a succession of years, nor for the same sorts generally; and the like holds good with all the constituent parts, and those slight traces of foreign substances, from differences of soil and plant, and little more, continually perceptible in wines. The same vines for two successive years will not bear fruit so exactly similar, as that some difference shall not be detected in the wine, and in the different proportions of its alcohol. The nature of the season in the same vineyard, and often under similar circumstances, will cause unaccountable changes. A warm year causes the

saccharine principle to be abundant, and, yielding more alcohol, gives a stronger wine, as is evidenced upon distillation. Nor is this natural effect more an impediment to classing wines by their alcoholic strength, than that of throwing in brandy, as in Portugal, during fermentation. By the wine being artificially brandied is prevented an accurate knowledge of its alcoholic strength, in the kind most commonly used in the British islands, as no two samples can be expected to show the same result. Thus it arose that the analysis of Dr. BRANDE was wrongfully censured, because it did not appear to be exactly what everybody supposed.

The Editor is of opinion that no port wine contains naturally more than fifteen per cent. of spirit—four or five per cent. are afterwards added to insure the wine keeping for years, in which time the artificial spirit becomes perfectly blended and mellowed in the wine.

The simplest method of ascertaining the amount of alcohol contained in wine is to distil the spirit from the wine, determining its specific gravity and quantity, and compare it with the quantity of wine taken; of course one of the first things to be considered, is how much wine to distil. The Editor takes generally one-third, and determines the alcoholic contents from it. If, for example, in the distillate thirty-three parts out of a hundred are composed of alcohol, the quantity of alcohol in the wine will be 11 per cent. for $\frac{33}{3} = 11$.

In the case of strong wines it is advisable to distil even more than a third, especially if a glass retort and water bath are used. Let the distillation be continued till at least half has passed over. If the density of the distillate is such as to yield twenty-five per cent. of alcohol, then $\frac{25}{2} = 12\cdot5$ per cent. of alcohol.

In strong new wines, undecomposed sugar and vegetal extractive matter may cause the evolution of more alcohol during the insensible fermentation. It may be presumed, notwithstanding, that if the quantity of alcohol in any wine exceed twenty per cent. it has been added artificially. All bottled wines, which improve at all, become sweeter, and old wines always appear to have gained in sugar. A very generous wine of the Drôme, in France, will afford a third of its weight in the brandy of commerce; in the department of the Herault there will not be more than a fourth part; in the Côte d'Or about an eighth of what is called prime brandy; in the department of the Charente, a still, charged with two hundred and forty litres of wine, yields from twenty-four to twenty-six of spirit, or about a tenth of the volume of the wine, and a little more in quantity of the second-class spirit; in the department of the Gard, from the same quantity of wine, forty litres of prime spirit, and about the same quantity of the second class. From these products it is easy to approximate to correctness in regard to the amount of spirit in wine, and thus it is seen that one-third spirit is given in first and second brandy of the Gard, while there is often a third distillation, which is not included.

In France it is found necessary to accommodate the Northern palate, by adding ten per cent. to the wines supplied to that part of Europe.

A tale, that BRANDE had only tested adulterated

wines palmed off upon him for genuine, was as silly as spiteful. Dr. BRANDE took the wines as he found them in the hands of the merchant, in a state awaiting consumption; and no rival examination showed a greater difference than might be expected to exist on all similar trials. The reader must bear in mind that it is nearly half a century since Professor BRANDE analysed the wines referred to. The Editor has always considered the per centage of alcohol given in genuine port to be too high, and this seems to be corroborated by the fact that samples of port, vintages 1820—1834, *et cetera*, kindly forwarded to him by Messrs. CHILLINGWORTH for experimental purposes, never gave more than *eighteen per cent. of pure spirit*. The 1820 had a specific gravity of '9945, and the distillate '9740 = 18·01 of alcohol; and the 1834 had a density of 1·0163, and the distillate '9723 = 18·99 of alcohol. Extractive matter in 1820 was 5·140, and in the 1834, 5·976 per cent. There is too frequently a disposition prevalent to cavil at scientific men and their statements because they are novel, or do not chime in with preconceived notions. The nature of the combination of the natural alcohol with wines is not now understood, but its effects just noted are undeniable. This combination cannot be supposed to be any other than one of those secrets, the discovery of which science will one day lay open. Annexed are the results of BRANDE, PROUT, and others, as to the alcohol contained in the well-known wines in common usage.

PORTUGUESE WINES.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Port,	25·83 ..	— ..	Brande.
Do.	24·89 ..	— ..	Do.
Do.	23·71 ..	— ..	Do.
Do.	23·39 ..	— ..	Do.
Do.	22·30 ..	— ..	Do.
Do.	21·40 ..	— ..	Do.
Do.	19·00 ..	— ..	Do.
Vinho de Ramo,	15·62 ..	— ..	Prout.
Do. average,	22·96 ..	— ..	Brande.
Do. average,	20·64 ..	0·9890 ..	Prout.
Do. weakest, ..	14·97 ..	— ..	Christison.
Do. strongest, ..	17·10 ..	— ..	Do.
Vinho de Ramo, mean of seven samples,	16·20 ..	— ..	Do.
White port,	14·97 ..	— ..	Do.
Colares,	19·75 ..	— ..	Brande.
Carcavellos,	19·20 ..	— ..	Do.
Do.	18·10 ..	— ..	Do.
Do. average,	18·65 ..	— ..	Do.
Lisbon,	18·94 ..	— ..	Do.
Do. dry,	16·14 ..	— ..	Christison.
Bucellas,	18·49 ..	— ..	Brande.
Vidonia,	19·25 ..	— ..	Do.

SPANISH.

Sherry,	16·81 ..	— ..	Brande.
Do.	19·83 ..	— ..	Do.
Do.	18·79 ..	— ..	Do.
Do.	18·25 ..	— ..	Do.
Do.	21·34 ..	0·9752 ..	Do.
Do. average,	17·17 ..	— ..	Do.
Sherry, very old,	23·86 ..	— ..	Prout.
Do. weakest,	13·98 ..	— ..	Christison.
Do. strongest,	16·17 ..	— ..	Do.
Mean of thirteen kinds,	15·37 ..	— ..	Do.
Do. long kept and East Indian,	14·72 ..	— ..	Do.
Mean of Madre de Xeres, ..	16·90 ..	— ..	Do.
Amontillado,	12·63 ..	— ..	Do.
Tint,	13·30 ..	— ..	Brande.
Alba Flora,	17·26 ..	— ..	Do.
Malaga, 1666,	18·94 ..	— ..	Do.
Do.	17·26 ..	— ..	Do.

MADEIRA ISLANDS, ET CETERA.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Madeira,	24.42	—	..	Brande.
Do.	23.93	—	..	Do.
Do.	19.24	—	..	Do.
Do. average,	22.27	—	..	Do.
Do. Sercial,	27.40	—	..	Do.
Do. do.	15.45	—	..	Christison.
East India, in cask,	16.90	—	..	Do.
Do. weakest,	14.09	—	..	Do.
West India, do.,	21.20	0.9908	..	Prout.
Red Madeira,	22.30	—	..	Brande.
Do.	18.40	—	..	Do.
Do. average,	20.51	—	..	Do.
Malmsey,	16.40	—	..	Do.
Do.	12.86	—	..	Christison.
Teneriffe,	19.79	—	..	Brande.

The analyses of **BRANDE** are calculated upon eighty-nine per cent. of alcohol and eleven of water; of **CHRISTISON** and **ZIZ** upon absolute alcohol.

FRENCH.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Claret,	17.11	—	..	Brande.
Do.	16.32	—	..	Do.
Do.	14.08	—	..	Do.
Do.	12.90	—	..	Do.
Do. average,	15.10	—	..	Do.
Do. first growth, 1811.,	7.72	—	..	Christison.
Do. Latour, 1825,	7.78	—	..	Do.
Do. Rose,	7.61	—	..	Do.
Do. ordinaire,	8.99	—	..	Do.
Champagne, still,	13.80	—	..	Brande.
Do. Mousseaux,	12.80	—	..	Do.
Do. red,	12.56	—	..	Do.
Do. pink,	11.30	—	..	Do.
Do. average,	12.61	—	..	Do.
Do.	12.10	—	..	J. Fontenelle.
Do. Burgundy,	16.60	—	..	Brande.
Do.	15.22	—	..	Do.
Do.	14.53	—	..	Do.
Do.	11.95	—	..	Do.
Do. average,	14.57	—	..	Do.
Do. 20 years in bottle.	12.16	—	..	Prout.
Hermitage, white,	17.43	—	..	Brande.
Do. red,	12.32	—	..	Do.
Côte Roti,	12.32	—	..	Do.
Roussillon,	19.06	—	..	Do.
Do.	17.26	—	..	Do.
Do. average,	18.13	—	..	Do.
Santerne,	14.22	—	..	Do.
Nice,	14.63	—	..	Do.
Barsac,	13.86	—	..	Do.
Vin de Graves,	13.94	—	..	Brande.
Do.	12.50	—	..	Do.
Do. average,	12.08	—	..	Do.
Grenache,	21.24	1.053	..	Prout.
Frontignan,	12.79	—	..	Brande.
Rivesaltes,	9.31	—	..	Christison.
Lunel,	15.52	—	..	Brande.
Do.	18.01	—	..	Fontenelle.

SICILIAN AND ITALIAN.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Marsala,	26.03	—	..	Brande.
Do.	25.05	—	..	Do.
Do. average,	25.09	—	..	Do.
Do. 21 years old,	18.20	—	..	Prout.
Lissa,	26.47	—	..	Brande.
Do.	26.35	—	..	Do.
Do. average,	25.41	—	..	Do.
Do.	15.90	0.9913	..	Prout.
Lacryma,	19.70	—	..	Brande.
Syracuse,	15.28	—	..	Do.
Do.	30.00	0.9911	..	Prout.
Etna, red,	18.90	—	..	Faraday.
Do. white,	18.16	—	..	Do.
Do. Sinical,	19.00	—	..	Do.
Do. white Falernian,	18.19	—	..	Do.
Do. red,	20.00	—	..	Do.
Aleatico,	16.20	1.020	..	Prout.

GERMAN.		Alcohol in 100 parts.	Specific gravity.	Analyst.
Hoeheimer,	14.37	—	..	Brande.
Do.	13.60	—	..	Do.
Do. old in cask,	8.88	—	..	Do.
Do. average,	12.03	—	..	Do.
Joannisberger, 1788, 9.38 parts acid in 100 by weight,	8.71	0.9978	..	Prout.
Rüdesheimer, 1811, 6.22 parts acid in 100 by weight,	10.72	—	..	Do.
Do. 1800,	12.22	0.9960	..	Ziz.
Do. superior,	8.40	—	..	Christison.
Do. inferior,	6.90	—	..	Do.
Hambacher,	7.35	—	..	Do.
Oestricher, 1801,	8.46	0.9960	..	Ziz.
Do. 1802,	10.50	0.9990	..	Do.
Do. 1804,	10.66	0.9920	..	Do.
Zornheimer, 1802,	10.11	0.9790	..	Do.
Do. 1803,	9.00	0.9960	..	Do.
Do. 1804,	8.75	1.0310	..	Do.
Bodenheimer, 1802,	13.96	0.9890	..	Do.
Rhenish, four years, un- der Soemmering's pro- cess, 10.58 parts acid by weight,	7.58	0.9997	..	Prout.
Do. natural state, 10.58 parts acid in 100,	7.36	0.9992	..	Do.
Do. three years under Soemmering's process, 8.4 parts acid in 100 by weight,	7.00	0.9968	..	Do.
Steinberger,	10.90	1.0025	..	Geiger.
Marcobrunner,	11.60	0.9985	..	Do.
Leibfrauenmilch,	10.60	0.9939	..	Do.
Geisenheimer,	12.60	0.9945	..	Do.

HUNGARIAN.

Tokay,	9.33	1.054	..	Brande.
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PERSIAN.

Shiraz,	15.52	—	..	Do.
Do.	12.95	—	..	Christison.
Do.	19.80	0.9944	..	Prout.

CAPE OF GOOD HOPE.

Cape Madeira,	22.94	—	..	Brande.
Do.	20.50	—	..	Do.
Do.	18.11	—	..	Do.
Do. average,	29.51	—	..	Do.
Cape Museat,	18.25	—	..	Do.
Constantia, white,	19.75	—	..	Do.
Do. red,	18.92	—	..	Do.
Do. do.	14.50	1.081	..	Prout.

REDDING has given an analysis in another form, as follows; but has not stated his authority:—

	Absolute Alcohol	
	Ounces.	Drachms.
Port, in bottle of 26 oz., seven years in glass,	2	7
Do. 25½ oz. one year in bottle, two in wood,	2	6
Pale sherry, 25 oz., three years old,	2	4
Another specimen,	2	7
Madeira, 25½ oz., two years old,	2	5
Cape, 25 oz., one year old,	2	8
Old hock, 21 oz.,	1	0
Brandy, 24 oz.,	10	0
Rum, 24½ oz.,	9	8

MULDER, who has had great experience in the analyses of wines and spirits, states that alcohol varied as follows:—

	Per cent.	
	by measure.	by weight.
Port,	20.70	to 23.20
Sherry,	15.40	24.70
Madeira,	19.00	19.70
Marsala,	19.90	21.10
Claret,	9.10	11.10
Burgundy,	10.10	13.20
Rhine wine,	9.50	13.00
Moselle,	8.70	9.40
Champagne,	14.10	14.80
Brandy,	52.40	53.80

Eighteen per cent. alcohol by weight are equal to about twenty per cent. by volume.

The wines of Palestine, Syria, and Asia Minor vary much in alcoholic strength. Those analyzed by Professor HITCHCOCK of Amherst College, United States of America, contained from ten to eighteen per cent. of alcohol, or nearly as much as the European wines, except those of Oporto, Madeira, and Sicily, or the low wines of Spain that are brandied.

Of late years Australia has become rather prominent as a wine-producing country. The Editor's brother, Mr. FREDERIC MUSPRATT, who has resided there for some years, writes as follows:—

Wine has been made in Australia during the last thirty years, but has not been known in the towns till within the last ten years, owing to the great demand for it in the country. The vine flourishes more or less in all these latitudes, but the climate of New South Wales must be admitted to be the best adapted for wine-growing, and vineyards are established on the banks of the Hawkesbury, the Nepean, the Hunter, the Williams, and the Paterson, which are capable of being greatly augmented, to meet any demand there may be made for wine; and a rapidly increasing population will doubtless hasten their extension. The quantity of wine produced in 1857 was about three hundred thousand gallons.

The wines best known in Sydney and Melbourne are Irrawang, Tomago, Caewarra, Camden Park, Kinross, Kalndah, Porphyry, Janilba, Wiventroe, *et cetera*, and the *crû* idiosyncrasy of the different varieties is as marked as is that of *Château, Lafitte, Margaux*, or other European wines.

A Burgundy wine is best at Irrawang; a champagne at Kaludah and Caewarra; a medoc at Tomago, Kinross, and Janilba; a hermitage at Porphyry; a muscat at Camden Park; and a Grâves at Janilba.

The vineyards are principally worked by Germans, and the cellar-masters have learned their craft at Frankfort-on-the-Maine in Europe; so the local prejudice against colonial wine, manufactured formerly under the superintendence of squatters, who never had any experience in wine-making, is rapidly disappearing, the grape being richer in sugar than that grown on the Rhine-board. The ordinary wine of the country is considered generally to be superior to that of Germany. There has not been time to test, on a large scale, the capability of producing extremely fine wines, but, judging from the fact, that wine thirty years old is as rich in flavor and bouquet as wine the same age in Europe, there can be but little question as to the quality. At the Paris Exhibition of 1855, the jury, upon tasting a red wine, two years old, called it a *joli vin, beaucoup d'avenir*, and awarded it one of its highest numbers. All present expressed their surprise at the result of the examination, and highly approved of the wines. The foreman said they were perfectly astonished at the quality of the Australian wines, and were unanimous in giving them a place, for strength and flavor, between the wines of Madeira and those of the *Côte du Rhone*.

A Sydney trade-circular, in describing the wines at present in the market, says:—The wines of this colony are essentially Australian in general character. They

assimilate to the French and German wines. Some are considered by connoisseurs to resemble hock, Sauterne, claret, Burgundy, and the like, but no attempt is made to imitate these or any other wines. Of course, the vines are in great variety, but, from whatever description of grapes they are made, each vineyard has a peculiar local character, distinguishable by vinists. The Camden wines will first be noticed. These are of three sorts, namely—white, which resembles the Rhenish wine; red, which approaches Burgundy in taste; and muscat, rather like the Frontignae of the Cape, malmsey, or Madeira. Now for the Irrawang wines. The white is considered like hock or Sauterne; of the red there is at present no stock; and the sparkling Muratta is a very fair champagne. Next, the Wiventroe wines will be referred to. These are—the white Muscat, resembling hock; red, corresponding in flavor with Rhenish wines; Madeira, which is of a Frontignac description; and Reissling. There are some wines grown at Oatlands, near Paramatta—the red resembles a claret, and the white corresponds with a light French wine. Under the head of Notes and Queries in the *Spectator*, is the following:—The samples of Australian wine at the Paris Exhibition have earned special commendation. When the horticulturists of that colony shall have succeeded in extending the cultivation of the vine over the land of the dreary Encalyptus, one may imagine that it is destined to the nurture of a British BACCHUS, and may look forward to the importation of Australian wines; and upon its arid soil, even upon the chasm of pools that its rivers present in the summer, would be exhibited the same miracle which is to be seen in the South of Europe, the juicy grape growing upon a parched soil, and for a season would be clothed with the loveliest foliage under the sun. Fancy the change of character that must come over the British stock habitually living in such scenes, under such a sun, with such a diet. It will be an experiment somewhat such as the world might have witnessed had the Saxon been planted in Italy. These queries are curious, as indicating the notions of the untravelled; but parties are daily getting more accurate knowledge as to the actual capabilities of the British Colonies.

The vineyards in the neighborhood of Adelaide, South Australia, are rapidly extending, and on the banks of the Murray and Murrumbidgee; the wines that are grown there will bear comparison with those of other lands. The only drawback to a rapid increase in the wines made in Australia lies in the dearth of labor; but as all the farmers along the thousands of miles of river banks are all planting their small vineyards—which may be tended by their wives and children—and as merchants, who will buy the juice and await its ripening, are establishing themselves at convenient places, there is every prospect of the trade becoming greatly enlarged.

In the ripening of wines Australia possesses an advantage over Europe. As there is no winter there, so is there no check to the fermentation after the juice has been removed from the vats to the casks. This check to the fermentation in Europe is the cause of much wine *fouling*, and is the mother of many of the

so called *sicknesses in wines*. This is a source of great anxiety to many of the large European *vignerons*. On account of the hot winds in Australia, the vines are pruned low; and as this method, combined with a hot sun, causes more *must* to be in the grape than is usual in Europe, it is found that the fermenting juice will, as a rule, bear a large quantity of *stalk*; the consequence is, that the elements of bouquet are much more prominent than with wines of the same strength in Europe.

The foregoing remarks are well worthy of attention. Good and sound wines doubtless have been made in Australia; but the Editor is not so certain whether the English will ever admit any wine produced in the colonies to be equal in that beautiful aroma—which science has not yet been able positively to assert what it is—and flavor belonging to the first-class wines of Europe—Johannisberg, Sauterne, Rudesheimer, Liebfraumilch, *et cetera*.

In 1852, specimens furnished to Baron LIEBIG will explain the result of an attempt at wine-making in that colony. This wine, principally from the grape called the pineau noir and gris, carried a specific gravity of 0.992, and gave 16.20 per cent. of alcohol; 0.505 of free acid; 3.265 of dry residue; and 0.498 of incombustible ashy constituents. Another species of white wine grown at Irrawang had a specific gravity of 0.94; gave out thirteen per cent. of alcohol; 0.66 of free acid; 3.313 of dry residue, chiefly saccharine; and 0.563 per cent. of ashy constituents—proportions met with in some of the European wines, particularly the German. LIEBIG also analyzed other wines of Australia, and among them one obtained from the white muscat grape, which gave 19.53 per cent. of alcohol and 0.64 of free acid.

The wines of South America have not been analyzed. They are scarcely known in Europe. There is, however, a red wine made at Chili which is much liked by Frenchmen, and is considered a very fine *vin ordinaire*; instances being known of French men-of-war putting in to Chili and stocking their vessels with hogsheds of it.

The difference in the intoxicating effect of wine, and brandy and water, it has been asserted does not exist. Professor BECK, taking brandy at 53.39 of alcohol, calculated strong Madeira at 48.26; weaker Madeira, 36.14; port, average, 42.33; Bucellas, 35.21; sherry, 33.75; Sauterne, 24.34; claret, 21.38. He is of opinion that the difference between wine and brandy and water is more fanciful than real. New wine is more intoxicating than old, although the latter is more spirituous; and, according to SOEMMERING, loses of its aqueous parts by age. BRANDE, with good reason, supposes that when brandy and water are allowed a sufficient time for combination, the intoxicating power may not be more than that of wine containing an equivalent of brandy. Thus the effect of brandy and water arises from their imperfect union. On the other hand, it is certain, that the evil effects of the two, when taken in excess, upon the animal system are very different. Fine pale cognac—HENNESSY or RENAULT's—with water, is often prescribed for invalids, and with great success. The Editor is of opinion that such a beverage taken constantly is less injurious than heavy, and especially drugged wines.

In some places in the North of Europe wine has been exposed to severe frost, under the idea of imparting strength to it, by drawing off the unfrozen portion. In the Augustan age, when the Euxine sea used to be frozen over, the wine in the casks, it is said, was cut with hatchets. Mr. PARKES experimented on wine exposed to 22° below the freezing point. He could discover no difference in taste between the fluid frozen and unfrozen, and thought the unfrozen the more vapid of the two. Of five hundred and sixty grains of port wine, five hundred and forty remained liquid; and of sherry two hundred and eighty-five grains were frozen, and one thousand and fifty-six remained in a fluid state—a result not in accordance with the experience of the colder wine countries of Europe.

The various matters discoverable in wine are not all found in the same growths. Less or more in some, and none at all in other kinds, with ever varying quantities, render analysis only good in relation to single specimens, and of no service in laying down a general rule for all. Thus water, sugar, alcohol, gum, extractive and nitrogenous matter, or albumen; the bitartrate of potassa, sulphate of potassa, chlorides of potassium and sodium, and in red wine coloring matter, and tannin from the stalks; carbonic acid in sparkling wine, and a perfume or bouquet, a species of ether—*enanthic*, *acetic*, *et cetera*—found in the fermentation, and citric acid—a mere trace of the latter—have been found in wine. Malic and gallic acid were thought at one time, with tartar and sugar, adding the gluten, to be almost the entire of the principles discoverable, and that all wines were the same in this respect; but science has undeceived the world upon this point. The amount of sugar in some sweet wines is full thirty per cent. according to PROUST. White wines are more perfect than red, and will endure longer; perhaps arising from the absence of the acid taken up by gypsum in the making, which cannot be used in red wines. The color of the red wines sometimes approaches to black from intensity. Indeed, a powerful wine in France carries the name of the Black wine of Cahors, generally used for strengthening weak-bodied or light-colored wines. Port wine of the vintage 1812, and that of 1820—CHILLINGWORTH—are nearly black, although upwards of forty years old. From pink to black in red exist, and from water to a deep golden hue in white wines, and even a green color in the wines of Cotnár. Amber and brown in different shades are to be met with, but no merit in regard to the quality of the wine attaches to the hue, however agreeable one more than another may be to the vision. Perhaps the clarets—so named from the French *clair*et, which, however, attaches to a different species—hold the middle place in regard to color, between the light red and black. The coloring matter in red wines may be obtained by an exposure of the bottle to the sun's rays, when it will fall in flakes; the taste of the wine remains unaltered. Before adding lime water the coloring matter is precipitated with the insoluble salt formed by the wine and acid of the wine in union. The finer wines are generally those in which the color is most attended to by the maker, and the rivalry in this respect is considerable. It is a matter in which preju-

dico operates. Many people cannot be persuaded that a pure red wine, of a light color, may be far superior as a wine in every good quality to one deeply colored, even when perhaps, as in port wine, it is aided by the elderberry.

When red wines lose color on the Continent they are said to be *rancio*, rusty; in England tawny. The coloring matter deepens on the deposit of tartar, and the tawny hue arises from age. Heat, too, will injure the color, which is thus not necessary to the flavor of the wine, being no way dependent upon it. Carbonate of potassa, sometimes formed in wine, injures both the color and flavor. It arises from the decomposition of the tartar, and in France is called the *tornure*. A little tartaric acid being added, the potassa forms cream of tartar, depositing crystals.

Wines grow darker as they ameliorate up to a certain point, but this is not uniformly the case. The alcohol in the wine, diminishing by evaporation, has no relation to this change; indeed, it is probable, that the aqueous portion evaporates rather than the spirituous. The specific gravity of wine increases under those circumstances. Many affirm that the alcohol in bottled wine increases by age; MULDER asserts that such a statement is thoroughly false, the formation of alcohol in the bottles being impossible. SOEMMERING discovered, that there were substances which permitted the aqueous portion of wine to escape more freely than the alcoholic. Equal parts of alcohol and water were placed in a glass vessel, and the mouth closed with a piece of bladder.—See ALCOHOL. It was observed, that under the circumstances more water was lost than alcohol, but when the temperature was raised to 62° it passed through the bladder unchanged. From this, and other experiments, SOEMMERING took the idea of ameliorating wine by exposing it to a similar process. He, in consequence, covered a glass vessel full of wine with a bladder, and suffered it to remain eighty-one days aside in a warm dry room. During that time one-half had evaporated, and the residue had acquired a more spirituous, mellow, and agreeable flavor. The color was deepened, a film had formed over the wine, and a deposit of crystals had taken place at the bottom of the glass. The proportion of alcohol had doubled from 4.0 to 8.0. A repetition of the experiment gave the same result, and thus a more rapid mode of ameliorating wine was discovered, than keeping it in wood, to effect the disengagement of the alcohol and water by time. Hence the transportation of wines to a tropical climate and home again, exposing the wine to aqueous evaporation, easily accounted for the beneficial effect, and the same with heat artificially applied. Wines thus exposed, too, deposit rapidly. Thus it is a common trick with port wine-mixers to place the bottles in water, carry it to the boiling point, and then, taking them out and placing them in the cellar, *the crust so admired by the ignorant in port wine is immediately formed*. It has been advanced, in consequence of the foregoing discovery, that the amelioration of wines in the wood is effected mainly by the disengagement of some of their water—the alcohol being retained, or a smaller proportion of alcohol than water being evaporated, the rest of the wine becomes more

concentrated—and that for this purpose vessels are most desirable which will retain the alcoholic and permit the aqueous particles to escape. Wine is observed to evaporate more rapidly in chestnut casks than in those of oak or similar close-grained timber. To such an extent is this evaporation carried in chestnut casks, that the French have prohibited the exportation of brandy in any but what are made of oak. Hence it may be conjectured, that the larger the surface of the liquor exposed the more rapid will be the evaporation; and that as the fermentation is quickened by the larger bulk in action, so it is with vinous amelioration. There is probably a limit here, which it would be very desirable to ascertain, but to which discovery no approximation has yet taken place. The Germans of late years, as they have discovered that, beyond the point of maturity in wine, the long keeping once thought of so much importance is not really of any great moment, seem also to have discovered that tuns of a moderate capacity are fully as advantageous as the gigantic vessels, by their fathers deemed of so much moment, for mellowing their Rhine wines.

Wine is continually sophisticated and adulterated, especially such as is of a coarse nature, having no obvious standard of taste. Of such wines port is, from the common usage, and the different flavors imparted to the wines of that name, the most abused. It is clear that a wine of any given species, if pure, will differ very little more in flavor in any season than the strength or weakness of the must will occasion. The main characteristics of the wine will be present. In a first-class Burgundy wine, for example, it will always be possible to distinguish that the wine is the growth of the country assigned, and no other wines will be drank in its place that are not of the same order. This would be the case with all sound good growths, and with the wines of Oporto as well, had they not been continually deprived of their natural character by mingling, coloring, and brandy adulteration. A house—Ireland and Company of Bristol—was renowned for its excellent Bristol port wine, and a handsome fortune realized. All at once, on the breaking out of the French revolutionary war, Bristol ports were no longer to be had, and Ireland and Company wound up their affairs, because they could no more obtain the wines of the South of France, for which they were celebrated as port-wine merchants, not a cask of their wines having ever been in Portugal. Now, such a deception could not be practised with Burgundy, champagne, or the finer wines of France.

The Editor has repeatedly had *English-made port* sent to him, but the imitation in no instance deceived him. The *taste* was sufficient to detect the imposition.

The mingling of inferior wines with superior, or with brandy, is not the sophistication for which the chemical professor is so much required to confer a boon upon the public, as in detecting extraneous substances of no vinous character at all. To brandy intermixed with wine, and which never blends with it as the natural alcohol of the wine does, are owing, in many cases, the liver complaints of the wine drinkers in England—a disease rare in wine countries.

The alcohol in wine may be ascertained by adding

one part of a concentrated solution of subacetate of lead to eight of wine by measurement. A precipitate is thus formed: agitate the mixture for a few minutes; pour the whole upon a filter; and then collect the fluid. This fluid consists of the spirit and water, with a portion of the lead. Now add by little and little *pure*, warm, dry subcarbonate of potassa—not the salt of tartar, and subcarbonate of potassa of commerce—which has been freed by heat from water. This must be done until the last portion remains undissolved. The spirit in the fluid being thus separated by the potassa abstracting all the water, the former will be found a stratum upon the salt. The experiment should be made in a glass tube, from half an inch to two inches in diameter, graduated into a hundred parts; and thus the quantity of spirit may be read off at sight.

To detect elderberry coloring in port and other red wines, acetate of lead is the simplest test. With pure red wine it throws down a greenish-grey precipitate. A deep blue precipitate is the result of elderberries, logwood, and bilberries. Brazil wood and red sanders are thrown down red. Lime water destroys the color imparted by beet.

WATSON in his chemical essays, as to his assertion that lead has been used in wine, is contradicted by the best French chemists, who have never been able to find a trace of its usage, and assert that it cannot be of any service. In England, among the fabricators and amenders of base wines, sugar of lead and litharge have been ignorantly applied for cleansing white wines rapidly, according to their own statements. Ignorance and vice generally travel abreast. Thus to keep wines from turning, some one of the vulgar receipts has proved a very harmless one—Put in fair water a pound of lead which has been melted; then into the cask, pretty warm, and stop it close! Oyster-shell lime has been used for the same purpose, an ounce to two gallons of the wine. Cochineal, to the extent of half an ounce dissolved in wine or brandy, is one means used to improve color; and for port wine the compound called *geropiga* made in Portugal, and imported into England openly, as a *liqueur* solely for sophisticating port wine. Port and claret are rendered rough by baking two quarts of sloes in a gentle oven, or over a slow fire, until their moisture is given out. The fruit is squeezed, and a pint of the liquid is applied to thirty or forty gallons of the wine.

Substances native, such as genuine must, wine, alcohol, or sirup—that is, boiled wine—can alone be tolerated in mixing. All besides is more or less a fraud. The object of mixing litharge, potassa, and tartrate of potassa, is to arrest bad flavor and temper sharpness in new wine. Some substances for color, sugar and honey to sweeten, spices to improve the flavor, and perry and water to increase the volume, are complained of in France. There is a commission there of able chemists, who examine samples of wine with great care. First, as to litharge—a poison—no one instance of its use has ever been detected. In 1824 a petition was presented to the French chamber of deputies, making such a charge against the wine merchants generally, that the public were alarmed, and an inquiry was instituted. The result was, that no single instance

of the employment of litharge could be substantiated—that, chemically speaking, litharge was a substance which, from experiment, contributed more to the deterioration than the preservation of the wine, and the merchants had no interest in its use. The petition was rejected as without foundation. In analyses of the wine for fifty-five years, the French council of health never met with the traces of such a substance in wine. They only stated that they had to complain, that too much water and often perry had been mingled to increase the volume of the wine. Sirup of dried raisins had been used with colored water, and fermented and sold to imitate the wines consumed in cabarets, but never any deleterious substances, under countless analyses. M. JULLIEN experimented upon this substance in 1824. In a litre of musk in a state of acetous fermentation, one gramme and a half of powdered litharge was mingled and agitated several times for twenty-four hours, and then suffered to rest. The wine was tasted two days afterwards, and found as acid as at first, and unchanged in color. It was then filtered, and sulphuric acid being added, the white precipitate of the sulphate of lead was scarcely perceptible; but the sulphide of potassium, in another part of the liquid, caused a precipitate of the color of the lees of the wine. The result of four analyses was, that litharge did not deprive wine of its acidity, and contributed more to its decomposition than preservation; that in any considerable quantity it destroyed it, and that in a small quantity it remained in the wine in a state to be recognized with facility. If used in domestic wines, the same effect would follow. It was probable that the tartar of the wine had been mistaken for it. After all the scientific researches of foreigners into the nature of wine, they have not succeeded in detecting the quantity of perry, water, and not insalubrious ingredients, added by the dishonest dealer.

Frauds in blending wine, often too common, are not managed with substances foreign to the grape. The rinsings of brandy and rum casks, Cape wines, cider, coloring matter, and tartar, or anything which will form a basis with Benecarlos, Figueras, red Cape, mountain, tartar, gum-dragon, cider, for port; and for coloring it red sanders infused for fourteen days in spirit of wine. Port is also made with that wine, twelve gallons; spirit of wine, six; brandy, three; rough fine cider, forty-two. A strong decoction of Brazil wood and alum imitate the favorite crust. Sherry is imitated, but the low-priced wine mingled with Cape answers the end. The notion that lead helps bad wine is current in England. But little faith is to be placed in such reports, since it has not the effect ascribed to it. Sulphide of hydrogen gas will detect lead in wine, turning it deep brown or black. Alum, sometimes used for astringency, or for the purpose of brightening the color, or of clarifying newly made wine, may be detected by first decoloring the wine—if red—by means of animal charcoal, previously washed with hydrochloric acid, filtering, and evaporating the liquid to about one-third of its volume in a porcelain or platinum capsule, and refiltering. If a precipitate has been formed while concentrating; if potassa, soda, or

chloride of ammonium produces when poured into the filtrate, a white precipitate soluble with the aid of heat in excess of alkali; if carbonate of potassa or soda produces a white deposit; if nitrate of baryta or chloride of barium produces also a white precipitate insoluble in acid, *alum is present*; or as NORMANDY further adds, a given portion of the wine may be evaporated to dryness and ignited, the residue treated with a little hydrochloric acid, evaporated to dryness and re-treated with dilute hydrochloric acid. If now the addition of caustic potassa produces a white gelatinous precipitate soluble in excess of alkali, but which is reprecipitated by chloride of ammonium, then alum is present.

Not to follow these deceptions further—the field it may be inferred is a wide one for the investigation of science, by researches into the defects of wine itself, and pointing out proper remedies—the inequality in must of the product of the grape, from so many causes, requires to be obviated; but no rule can yet be laid down by which existing evils can be certainly avoided. Among the curious facts in relation to pure wines are the character of their deposits, so varied in form and density, according to the growth of the vine and temperature of the year when the vintage occurred. Some are oily, others muddy, adhering to the side of the bottle; and some are very light, so that on the least movement they mingle with the wine. Oftentimes the same wines will make a deposit in two different forms in the same bottle, one adhering to the sides or uniting in a mass at the bottom of the wine, the other suspended in the liquor. One species of deposit resembles litharge, and no doubt caused the report of its usage. In champagne wine the deposit is called *depot-pierre*, a precipitate in the form of very fine sand, or little scaly crystals, which are the tartar naturally deposited. All wine residuums contain more or less of this substance, but it is often so enveloped in the oily or muddy parts of the precipitate that it is not apparent. It is heavier than other deposits, and when mingled with the wine does not communicate any bad taste, alters its clearness very little, and when shaking the liquor ceases it falls to the bottom. This deposit is found in the better wines, and those having it preserve their excellence a long time, and are less subject to disarrangements than the wines the residue of which floats in the liquid. In order to investigate the nature of this substance, it is dried and placed upon burning charcoal. In consuming it emits an odor of burnt tartar, and on keeping up the fire, leaves a white residue which is found to be potassa.

The choicest wines keep the longest in bottle, and deposit there so much that, in order to have the wine perfectly limpid, it is necessary to decant them with great care. It is useless to place them in different bottles for no other reason but to secure transparency, as they will soon begin to deposit anew. Unless they are to be removed to a distance, or there is a fear of their acquiring a bad taste, they should remain untouched. This operation, when necessary, is to be performed with great care. Small glass or tinned siphons have been tried for delicate French wines, but not with the desired success. Crape or gauze has its inconveniences. An

instrument called a *cannelle-aérifère*, invented by M. JULLIEN, is used for the purpose in France, as well as for chemical transfusions. For champagne more particularly it is well adapted. Wine is sometimes placed in demijohns, which hold from thirty to sixty bottles each, by which means it is well preserved; but the inconvenience of stirring up the deposit is in no way lessened on attempting to transfer their contents.

The disproportionate allowance of brandy thrown into wine is after all the great evil encountered in the wines destined for British consumption, and this is always to be detected by science. All wines of the highest class are deemed too weak and thin. The merchant imagines that it prevents acetous fermentation, and he knows that it blends all qualities into that which is most plentiful. Dr. M'CULLOCH denied that it suspends acetification; Mr. CADET says, that if administered to the one-seventieth of the entire value it will do so. Alcohol is not separated by the action of heat, since it has been effected at 56°; but, however, this may be, wine to which brandy has been artificially added, affects the nervous system to a degree far greater than wine in the natural state, and chemistry has not yet been successful in discovering any theory which will account for it. The following tables show the importations of wine and the amount for home consumption for the years mentioned in the respective columns:—

TABLE OF WINE IMPORTATIONS.

Years.		Tuns. French.		Tuns. Portuguese.
1675	.....	7,495	.....	20
1676	.....	9,645	.....	83
1677	.....	6,789	.....	176
1678	.....	7,212	.....	199

French war—wine prohibited.

Years.		Tuns.		Tuns.
1679	.....	3	.....	1,013
1680	.....	1	.....	1,003
1681	.....	..	.....	1,718
1682	.....	..	.....	13,860
1683	.....	..	.....	16,772
1684	.....	..	.....	11,611
1685	.....	..	.....	12,885

French again admitted.

Years.		Tuns.		Tuns.
1686	.....	12,760	.....	286
1687	.....	15,518	.....	327
1688	.....	14,218	.....	448
1689	.....	11,109	.....	579

Here the French imports again interrupted. From 1697 inclusive, the returns were more exact and given in gallons, *videlicet*, together, French, Spanish, Portuguese, and Rhenish.

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds.	Galls.
1697	13,086	3	43	1707	12,962	0	16
1698	12,974	2	15	1708	14,380	0	50
1699	21,553	3	25	1709	13,338	1	48
1700	23,502	0	10	1710	15,869	0	56
1701	21,443	2	23	1711	15,481	2	14
1702	15,725	1	62	1712	12,677	1	27
1703	11,092	2	42	1713	15,937	1	8
1704	13,811	1	57	1714	18,747	1	57
1705	12,070	1	17	1715	21,751	0	9
1706	10,973	2	31	1716	18,834	3	7

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds.	Galls.
1717	22,260	3	58	1771	16,874	2	12
1718	23,875	1	48	1772	15,597	2	42
1719	20,510	2	13	1773	16,431	3	20
1720	19,111	0	44	1774	17,992	1	20
1721	25,263	0	45	1775	17,736	0	13
1722	25,470	0	42	1776	16,734	0	36
1723	22,415	1	1	1777	18,217	2	60
1724	23,075	3	8	1778	16,343	0	51
1725	24,722	3	35	1779	12,760	2	10
1726	19,334	0	24	1780	20,514	2	39
1727	21,064	3	61	1781	13,311	3	20
1728	30,045	2	32	1782	9,791	0	39
1729	25,672	3	50	1783	13,624	1	51
1730	19,823	3	31	1784	14,499	0	56
1731	24,239	1	58	1785	16,287	0	58½
1732	21,384	0	11	1786	16,242	3	53
1733	21,420	1	57	1787	23,324	3	33
1734	21,264	1	47	1788	25,560	3	52
1735	24,416	1	28	1789	26,299	2	60
1736	20,763	0	10	1790	29,144	3	13
1737	26,605	1	38	1791	33,155	1	33
1738	22,171	2	1	1792	35,525	3	51
1739	18,594	3	28	1793	22,788	3	40
1740	15,198	3	60	1794	30,259	2	2
1741	17,178	1	3	1795	35,608	3	54
1742	16,715	3	58	1796	23,693	1	37
1743	17,655	0	34	1797	15,904	2	30
1744	10,276	2	60	1798	23,287	3	49
1745	16,034	1	34	1799	33,419	3	7
1746	12,205	1	11	1800	32,332	1	26
1747	14,560	2	32	1801	38,893	1	21
1748	15,135	1	16	1802	30,107	0	53
1749	21,555	0	35	1803	37,913	1	62
1750	15,456	2	11	1804	19,419	3	2
1751	14,788	0	2	1805	33,463	0	55
1752	13,708	2	52	1806	35,910	0	55
1753	18,857	0	20	1807	39,789	3	29
1754	14,982	3	50	1808	47,143	3	49
1755	16,544	2	22	1809	49,762	3	17
1756	12,264	2	18	1810	47,058	3	25
1757	14,050	2	30	1811	20,787	1	4
1758	15,896	1	54	1812	35,082	1	17½
1759	15,405	2	19	1813	..	..	..
1760	15,427	3	47	1814	31,465	2	36
1761	14,602	3	46	1815	30,874	0	20¾
1762	16,097	0	1	1816	18,218	0	57½
1763	17,082	3	21	1817	27,073	0	1½
1764	17,390	1	42	1818	35,763	2	9½
1765	18,132	1	4	1819	23,407	0	33½
1766	18,472	0	14	1820	22,781	1	55¾
1767	17,087	3	5	1821	24,125	0	2½
1768	18,580	0	58	1822	27,454	2	25
1769	18,371	2	30				
1770	16,724	0	40				

The Methuen treaty to favor Portugal at the expense of France was signed in 1703—the duty on French wine to be one-third more than on that of Portugal. A tun of wine is two pipes, four hogsheads, or two hundred and fifty gallons old measure, or two hundred and thirty-one cubic inches. From the year 1785 the returns include all sorts and quantities of wine, however small. In 1813 the records were destroyed by fire at the Custom House.

About this time the returns were made in imperial gallons, the old measures being abolished.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1823	6,670,355	1835	9,039,551	1847	7,938,067
1824	6,637,506	1836	9,406,083	1848	7,536,730
1825	10,892,033	1837	8,033,480	1849	7,970,067
1826	7,586,937	1838	8,518,484	1850	9,304,342
1827	7,950,961	1839	9,909,056	1851	9,008,428
1828	9,637,951	1840	9,311,247	1852	6,793,304
1829	7,618,196	1841	7,708,502	1853	11,029,567
1830	6,879,588	1842	7,216,113	1854	10,875,855
1831	7,116,870	1843	6,807,053	1855	8,916,766
1832	6,018,480	1844	8,584,586	1856	9,171,691
1833	7,443,841	1845	9,469,776	1857	10,336,845
1834	9,766,116	1846	7,711,309	1858	5,791,656

TABLE OF WINE CONSUMPTION.

Wine consumption and proportion to population. Down to the year 1787 the importation and consumption were nearly equal.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1787	4,521,941	1811	5,629,722	1835	6,420,342
1788	6,650,641	1812	5,924,530	1836	6,899,212
1789	5,959,098	1813	4,565,477	1837	6,391,551
1790	6,601,038	1814	5,320,774	1838	6,900,271
1791	7,573,790	1815	4,624,105	1839	7,000,486
1792	7,851,707	1816	4,957,638	1840	6,553,922
1793	6,610,701	1817	5,142,820	1841	6,184,860
1794	6,811,374	1818	5,635,216	1842	4,815,222
1795	8,238,438	1819	4,615,212	1843	6,938,887
1796	5,776,260	1820	4,586,495	1844	6,838,684
1797	3,569,261	1821	4,686,885	1845	6,765,131
1798	5,265,768	1822	4,606,999	1846	6,740,316
1799	6,138,164	1823	4,845,960	1847	6,053,847
1800	7,294,752	1824	5,030,991	1848	6,120,547
1801	6,876,710	1825	8,069,542	1849	6,251,852
1802	7,113,416	1826	6,058,443	1850	6,427,222
1803	8,226,464	1827	6,826,361	1851	6,284,653
1804	5,457,691	1828	7,162,376	1852	6,246,661
1805	4,622,701	1829	6,217,652	1853	6,813,830
1806	5,825,178	1830	6,434,445	1854	6,775,858
1807	6,271,346	1831	6,212,264	1855	6,873,441
1808	6,331,875	1832	6,965,542	1856	7,567,574
1809	5,894,177	1833	6,207,770	1857	7,042,642
1810	6,521,293	1834	6,480,544	1858	6,637,146

The wine consumption, with a population of about eight or nine millions in 1787, augmented to nearly twenty millions of souls in 1851, showed little increase, in consequence of the duties on several classes of wines reaching fully to 500 per cent. That the means of purchase increased with the population, is shown by the augmented value of property assessed in 1803 = £115,351,952, and in 1843 = £181,322,202.—*James on the Wine Duties*, 1855. If, with eight or nine millions of souls, we consumed seven millions of imperial gallons, with twenty millions of population we should have consumed double that quantity, in place of no increase having taken place—spirit having been substituted.

	Imperial Gallons.	Population.
1787 to 1792	39,158,218	8,000,000
1793 to 1798	26,871,802	8,500,000
1799 to 1804	41,107,197	10,812,000
1805 to 1810	35,466,570	..
1811 to 1816	29,231,636	13,296,177
1817 to 1822	29,273,636	14,072,331
1823 to 1830 (8 years)	50,583,970	16,000,000
1831 to 1836	37,495,674	16,255,605
1837 to 1842	37,936,392	18,664,761
1843 to 1848	38,574,512	..
1849 to 1854	38,909,486	20,919,531

The consumption of wine was three and a half bottles per head from 1785 to 1794. It fell to three bottles from 1794 to 1814; and from 1814 to 1820 to two bottles. After that one and three-tenths bottle per head.

From 1786 to 1794 the Portuguese wine consumed in Great Britain, principally port, was 75·67 per cent., because there were only two-thirds of the duty paid upon the wines of Portugal that were paid on other wines. The duties were equalized in 1831, and from that time to 1854 the consumption of port diminished, until, in 1854, it was only 36·69 of the whole consumption. Spanish wines, only 16·67 in the first period, rose to 38·34 per cent.; French wines that were only 3·26 per cent., had risen in 1854 to 8·12.

Table of the proportions of different wines consumed in England, for which the Editor is indebted to Mr. JAMES, author of the *Wine Duties considered Financially and Socially, et cetera*, 1855:—

TABLE OF PROPORTIONAL CONSUMPTION.

Years.	Colonial. Per cent.	Spanish Per cent.	Portuguese. Per cent.	French. Per cent.	Sicilian. Per cent.	Madeira. Per cent.
1849	3·87	39·16	42·36	5·03	7·11	1·14
1850	3·82	38·36	43·73	5·29	6·61	1·09
1851	3·74	40·33	40·02	7·12	6·28	1·10
1852	3·82	41·08	39·23	7·05	6·12	1·1
1853	3·92	39·58	38·87	7·79	7·55	1·02
1854	3·75	38·33	36·67	8·15	11·32	0·06
1855	3·95	40·42	35·16	7·99	10·82	0·05
1856	4·02	39·81	34·03	8·33	10·43	0·57
1857	6·05	39·43	32·72	8·83	10·62	0·05
1858	10·89	39·67	28·69	8·54	10·33	0·05

Proportion of White to Red Wines consumed.

Years.	White.	Red.
1854	52·065	47·935
1855	54·32	45·68
1856	54·31	45·69
1857	54·85	45·15
1858	59·21	40·79

Cape import at half duty.

Cape consumption.

Imperial Gallons.	Imperial Gallons.
361,605	261,564
492,087	352,330
787,753	456,214
654,118	726,314

DECREASE IN IMPORTATION, 1858, COMPARED WITH THE PREVIOUS YEAR.

Total.	Pipes.	Decrease. Pipes.
French imports	1,742	504
Portuguese imports	14,240	3,332
Spanish imports	20,078	1,114
Sicilian imports	1,900	114
Madeira and Canary	192	52
From Holland	79	32
Other places	2,339	401
British Possessions	1,427	..
Total	41,997	5,549
		2,950 { Colonial increase at half duty deducted.
		2,599 Decrease.
		58 { Decrease mixed in bond.
		Total.....2,657 Pipes decreased.

The Cape wines at half duty increased in ten years, from 3·87 to 10·89. Spanish were stationary, or with a small increase. Portuguese decreased from 42·36 to 28·69. Other wines, except Madeira, increased.

In the monetary provisions of the government for 1860, the duties were reduced upon all wines of all countries and of our own colonies from five shillings and sixpence and five per cent., to take place on January 1, 1861, on wines of the lowest alcoholic strength, or not above 18°. These to be admitted at one shilling per gallon. The wines above this alcoholic strength at two shillings, or wines approaching 40° of proof spirit. This reduction to commence at first by a fall of duty to three shillings per gallon, from the existing five shillings and sixpence $\frac{2}{20}$.

The grocers' home made wines, free of duty, aided to supersede foreign wines in consumption, and thus injured the exchange of goods with the foreigner;

these wines or compounds having been sold at little more than the duty only on foreign wines.

The average product of wine in France is nine hundred millions of gallons; and in Paris two hundred and sixteen bottles per head are annually consumed; in Hamburg twenty-nine per head. The following table is the most authentic extant, and there is reason to think much within the real limit of the produce of the wines of Europe:—

	Gallons.
France	900,000,000
Hungary and Austria	500,000,000
Spain	220,000,000
Italy	195,000,000
German States, Prussia, Luxemburg, &c.	45,000,000
Portugal—total product	10,500,000
Sicily	3,000,000
The Azores	575,000
The Canaries	1,875,000
Cape of Good Hope 14,000 leaguers of 60 gallons	840,000
Cyprus, Commandery, Muscadines, &c.	30,000
Servia, Wallachia, &c.	170,000
Total	1,876,990,000

Greece produces four millions six hundred and forty thousand oke; Asia Minor, Syria, Palestine, Persia, and the East produce wine, as well as some parts of Southern Russia.

The following tables, from *Redding on Wines*, contain a selection out of a number of the fine growths, of the names and character of the wines produced in the principal countries in Europe. To extend the list would be useless. In France alone, there are six classes of red wine, seven of white, and five of *vins de liqueur*. There are four hundred and sixty-three red wines, two hundred and forty-three white, and nine *de liqueur*. The champagne wines alone reckon six degrees in quality:—

WINES OF THE FIRST CLASS.

FRANCE, SPAIN, HUNGARY, GERMANY, SICILY, NAPLES, AND CAPE OF GOOD HOPE.

Wines.	Country.	Place.	Character.
Romanée Conti.....	France	Côte d'Or	The first and most delicate red wines in the world, full of rich perfume, of exquisite bouquet and fine purple color; light, yet with body and spirit sufficient to render them pleasant and healthful in use.
Chambertin.....	"	"	
Richembourg.....	"	"	
Clos Vougeot.....	"	"	
Romanée St. Vivant.....	"	"	
La Tache.....	"	"	
St. Georges.....	"	"	
Corton.....	"	"	
First growths of Prémaux....	"	"	
Musigny.....	"	"	
Clos du Tart.....	"	"	Burgundies, closely resembling the above growths in aroma, and all their other qualities.
St. Jean.....	"	"	
Perrière.....	"	"	White, highly esteemed.
Veroilles.....	"	"	
Morgeot.....	"	"	Fine color and perfume, light, less warm than Burgundy, with a taste of the violet, and a rich purple hue.
Mont Rachet.....	"	"	
Lafitte.....	"	Gironde	Wines of the Rhône, darker in color than the preceding. Red Hermitage the most noted of these, of good body, and a fine flavor of the raspberry.
Latour.....	"	"	
Château Margaux.....	"	"	White, still, dry; of an amber color; generally iced for drinking.
Haut Brion.....	"	"	
Beaume.....	"	La Drôme	Fine effervescing wine, bright in color, slightly frothing.
Muret.....	"	"	
Bessas, Burges, Landes.....	"	"	The best of the white wines of Champagne, being all of the first quality, but differing a little in color and effervescence.
Méal and Gréfioux.....	"	"	
Racoule, Guionière.....	"	"	Fine white wines of excellent quality, lightish brown in color, aroma most agreeable, and some of rather sweet taste.
Sillery.....	"	Marne	
Ay.....	"	"	Description resembles the preceding.
Mareuil.....	"	"	
Hautvilliers.....	"	"	Full of body, spirit, and perfume. The white is the finest of all white wines.
Pierry.....	"	"	
Dizy.....	"	"	A rich muscadine.
Epernay—Closet.....	"	"	
St. Bris.....	"	Gironde	Straw wines, rich and luscious.
Carbonnieux.....	"	"	
Pontac.....	"	"	Ditto.
Santerne.....	"	"	
Barsac.....	"	"	Ditto.
Preignac and Beaumes.....	"	"	
Château Grillet.....	"	La Loire	A dry delicate wine.
Hermitage.....	"	Rhône	
Rivesaltes.....	"	Pyrénées Orientales	A fine, luscious, sweet red wine.
Colmar, Olwiller, Kaiserberg	"	Haut Rhin	
Kientzheim, Ammerschwir..	"	"	Remarkably fine red muscat.
Hermitage de Paille.....	"	Rhône	
Amontillado Sherry.....	Spain	Audalusia	Thick rich wines, known as Tokay, also Tokay-ausbruch.
Schloss Johannisberger.....	Germany	The Rhine	
Lacryma Christi.....	Naples	Naples	Very spirituous, by some preferred to Tokay. Greenish color.
Syracuse.....	Sicily	Syracuse	
Tokay Essence, and its first growths, called Tarczal, Szeghi, Zadany, Tolesva, also Erdo-Benye, Zambor, Tallya, Mada.....	Hungary	County of Zemplin	Thick, rich, and luscious.
Cotnar.....	Moldavia	Cotnar	
The Commandery.....	Cyprus	Com. D.	Luscious; two kinds.
Constantia.....	Africa	Cape of Good Hope	
Lagrimas.....	Spain	Malaga	Thick and luscious.

SECOND CLASS.—FRENCH.

Wines.	Place.	Character.
Verzy, Verzenay, Mailly, St. Basle, Bouzy, St. Thierry.....	Marne	Red wines of Champagne.
Vosne, Nuits, Chambolle, Volnay, Ponnard, Beaune, Morey, Savigny, Meursault.....	Côte d'Or	Excellent red Burgundies, very little inferior to first growths.
Olivotes, Pitoy, Perrière, Préaux.. Chainette, Migrenne.....	Yonne	Good wines.

SECOND CLASS.—FRENCH.—(Continued.)

Wines.	Place.	Character.
Moulin à Vent, Torins, Chénas....	{ Saône et Loire, } Rhône	Red.
Hermitage, second growths.....	Rhône	Red.
Côte Rotie.....	"	Red.
Rozan, Gorze, Léoville, Larose, Branne-Mouton, Pichon-Longue- ville, Calon.....	Gironde	Red.
Côteau Brûlé.....	Vaucluse	Red.
Jurançon, Gan.....	Basses Pyrénées	Red.
Roussillon, Bagnols, Cosperon, Col- lioure, Torémila, Terrats, Mas- deu.....	Pyrénées Orientales	Red.
Cramants, Avize, Oger, Menil.....	Marne	White Champagne wines, of good quality.
La Perrière, Combotte, Goutte d'Or, Genevrière, Charmes et Meursalt }	Côte d'Or	White Burgundies, of high repute in France.
Guebwillers, Turkeim, Wolxheim, Molsheim, and Rangen, in Belfont }	Haut Rhin	Dry, white, and <i>vins de paille</i> , of good repnte.
Arbois, Pupillin, Château Châlons..	Bas Rhin	
Coudrieu.....	Jura	Good wine, <i>mousseux</i> and still.
Langon, Cerons, Podensac.....	Rhône	{ A white wine, which keeps long, of fine <i>sève</i> and perfume.
Montbazillac, Tcaulet, Raulis, }	Gironde	White wines, capable of endurance.
Suma, Sancé.....	Dordogne	Good white wines of the country.
Buzet, Amazon, Vianne.....	Lot et Garonne	Generous white wines, of good body.
St. Peray, St. Jean.....	Ardèche	{ Delicate <i>mousseux</i> and <i>non mousseux</i> , of agree- able flavor.
Jurançon.....	Basses Pyrénées	{ White, with an agreeable perfume of the truffle.
Frontignan and Lunel Mazet.....	Herault	Sweet, rich, and luscious; white.
Bagnols, Collioure, Rodez.....	Pyrénées Orientales	Red, styled <i>de Grenache</i> , rich and sweet.
Maccabeo of Salces.....	"	Sweet, <i>vins de liqueur</i> .

THIRD CLASS.—FRENCH.

Wines.	Place.	Character.
Hautvilliers. Mareuil, Dizy, Pierry, } Epernay, Taisy, Ludes, Chigny, } Villiers-Allerand, Cumières.... }	Marne	{ Red Champagne wines of the second quality; light and agreeable.
Riccy, Avirey, Bagnoux la Fosse....	Aube	Resembling the preceding.
Gevrey, Chassagne, Aloxe.		
Savigny sous Beaune, Blagny, }	Côte d'Or	Good Burgundies of the third quality.
Santenay, Chénôve..... }	Yonne	Ditto.
Clairon, Bouvin.....		
Fleury, Romanèche.		
Chapelle Guinchay.....	Saône et Loire	Ditto.
Chantergues, Montjuset.....	Puy de Dome	Not wines of note; red.
Crozes, Mercuroi, Gervant.....	Drome	{ Resembling red Hermitage; a little less full and fine, might be called Hermitage of the third quality.
Seyssuel, Revantin.....	Isère	Red wines, very middling of the class.
Verinay.....	Rhone	Resembling Cote Rotie.
Pouillac, Margaux, Pes-ac, St. } Estephe, St. Julien, Castelneau } de Médoc, Cantenac, Talence, } Merignac, Canon..... }	Gironde.	{ Pouillac, St. Estephe, good light red wines; Castelnau mediocre; the other growths agreeable.
Farcies, Terrasse, Campreal.....	Dordogne	Resembling St. Emilion; keeping well.
Cape Breton, Soustons.....	Landes	Red; light colored, with a harsh taste.
Chuzelan, Tavel, St. Genies, Virac. }	Gard	{ Red wines, grown on the banks of the Rhone; will not keep good more than six years.
Ledenon, St. Laurent des Arbres }	Vaucluse	Good red wines; keep well.
Chateanneuf.....	Aube	Champagne; light and agreeable, white.
Riceys.....	Côte d'Or	Tolerable wine; not exported.
Rougeot de Meursalt.....		
Vannorillon, Grises, Valmure, }	Yonne	{ In considerable esteem in Paris as wines of the table. They are all white.
Grenonille, Vandesir, Bourger- eau, Mont de Milien et Chablis. }		
Pouilly and Fuissé.....	Saône et Loire	Much the same as the preceding.
Etoile, Quintignil.....	Jura	White.
Pujols, Ilats, Landiras, Virelade }	Gironde	White; of middling quality.
St. Croix du Mont, Loupiac.... }		
St. Michel sous Condrieu.....	Loiro	White; consumed in the country.
Frontignan and Lunel.....	Herault	{ Second growths of those famous and rich white wines.
Vins de Picardan of Marseillan } and Pomerols. Vins de Ca- labria, de Malaga..... }	"	{ Rich luscious sweet wines, prepared in the department of Herault, and very little ex- ported; also muscadines.
Roquevaire, Cassis, Ciotat. Vins }	Bouches du Rhone	{ Rich sweet wines, boiled wines, and malmseys, of good quality.
Cuits.....		

SECOND AND THIRD CLASSES.—GERMAN.

RHINE AND MOSELLE.

Wines.	Place.	Character.
Johannisberger	Johannisberg	{ Grown near the Schloss Johannisberger, in the list of first growths already given. A very fine growth.
Steinberger	Rheingau	
Rüdesheimer { Berg	Rheingau, six leagues from Mayence, facing Bingen; on the hill and slope behind the houses.	Lighter than Johannisberger; fine bouquet. A highly prized wine.
Hinterhäuser		
Laubenheimer	Mayence district	Lighter than Johannisberger, but delicate.
Kösterich	"	Ditto.
Niersteiner	"	A good wine, with fine flavor and body.
Oestricher	Worms	Ditto.
Liebfrauenmilch	The Rhine	Hence the word hoch. The first growth is the prime hoch wine of the importer. Light, agreeable—12·08, average of spirit. Some kinds, when new, contain as much as 14·37, according to BRANDE.
Zornheimer	{ Spire, on the } { River Mayn }	Choice wine, of fine flavor.
Hochheimer	Rheingau	Light, agreeable, good bouquet.
Gracfenberger	{ Near Mayence, } { the palatinate }	An excellent wine.
Gaubischeimer	"	Ditto.
Deidesheimer	"	An excellent wine, light and delicate.
Oppenheimer	"	Ditto.
Bodenheimer	"	Of first quality.
Nackenheimcr	{ Moselle, Treves } { district }	Ditto.
Brauenberger	"	Ditto.
Scharzberger	"	Ditto.
Graach	"	Ditto.
Zettingen	"	Ditto.
Wehlen	"	Ditto.
Piesport	"	Second quality.
Montagne Vert	"	Moselle, noted for diuretic qualities.
Causel and Valdrach	"	Secondary Moselle.
Rinsport	{ Moselle, Witlich } { canton }	Wine once in high repute.
Bacharach	Near Mayence	Secondary Moselle.
Becherbach	Becherbach canton	Called wine of the Ahr.
Walporzheimer	Upon the Ahr	Considered one of the Moselle wines.
Rutz	On the Moselle	A light Rhine wine.
Steeg	Near Bacharach	Inferior light Rhine wine.
Montzingen	"	A secondary wine.
Bodendorf	Near Bonn	Ditto, a Rhine wine.
Affenbourg Hamen	Near Coblenz	Ditto.
Strang	Near Neider Breisig	Ditto.
Elzenburger	"	Ditto.
Alzenburger	"	Ditto.
Lutz	Near Treiss	Ditto.
Maas and Huhn	Niedar Heimbach	Ditto.
Stugerboeg	Rhine	Ditto.
Engelhohe	On the Nahe	Called wine of the Nahe; secondary wines.
Neiderborg	"	Ditto.
Leinenborn	"	Ditto.
Bangert	"	Ditto.
Rosenhoch	"	Ditto.
Rensberger	Tarbach	Secondary Moselle.
Wurzgarten	Tarben	Ditto.
Amfuhr	{ Burg, left bank } { of the Rhine }	Ditto.
Rothenberger	Geisenheim	Soft, delicate, prime wine.
Scharlach	Mt. Scharlachberg	Fine flavored; rich aroma.
Roth	{ Near Hochheim, } { Spire district }	Hoch of good quality.
Königsbach	"	Ditto.
Weinheim	"	Ditto.
Forst	"	Ditto.
Ungstein	"	Ditto.
Schierstein and Narden	Wiesbaden	Tolerable wines.
Epstein	Near Frankfort	Middling wines.
Phillipsech	"	Ditto.
Reichenberger and Wildenstein	Erbach	Inferior Rhine wine in quality.
Fönerbach and Lanfen	{ Near Fribourg, } { at Badenweiler }	These are considered the best wines of Baden.
Heidelberger and Kleingenberger	Baden	Good wines of the country.
Reichenau Island	Lake of Constance	Ditto.

SECOND AND THIRD CLASSES.—GERMAN.—(Continued.)

RHINE AND MOSELLE.

Wines.	Place.	Character.
Meresberg and Überlingen.....	Near the Lake	Good wines of the country.
Cretzingen.....	Baden	Ditto.
Berghausen and Stellingen.....	"	Ditto.
Beringfield and Zeil.....	Bavaria	} Inferior wine.
Lindau and Ravensburg.....	"	
Schweinfurt.....	"	} Excellent wine, Rhenish character.
Liest.....	Württemberg	
Stein.....	"	Ditto, of a very dear price.
La Harpe.....	"	Inferior, but often sold for Stein.
Escherndorf and Schallsberg.....	"	Inferior to Stein.
Bischofsheim.....	{ Near Hanau, } Frankfort }	A tolerable wine, resembling Rhenish.
Calmus.....	{ Tricffenstein, } near }	A <i>vin de liqueur</i> .
Guben.....	Aschaffenburg }	} Very poor wines.
Meissen.....	Saxony	
Franconia.....	Franconia	A <i>vin de paille</i> ; aromatic.
Assmannshäuser.....	{ Rheingau, near }	{ Equal to the second class of Burgundy; excellent body.
Bessingheimer.....	{ Rüdesheim }	{ Well tasted, good bouquet; called wine of the Neckar.
Altenahr.....	{ Lauffen, }	} Inferior wines.
Mayschof.....	{ Wirtemberg }	
Rech.....	{ Rhine country, }	} Ditto.
Ahrweiler.....	left bank }	
Bruch.....	"	Ditto.
Creutzberger.....	"	Ditto.
Hoëmningen.....	"	Ditto.
Kesseling.....	"	Ditto.
Dernan.....	"	Ditto.
Blischert.....	Lintz	A tolerably good wine.
Neuwied Blischert.....	Hesse Darmstadt	Ditto.
Wangen.....	Bavaria	Poor, though esteemed in the country.
Naumbourg.....	Saxony	{ Like fourth class Burgundy; styled <i>vins agre-</i> <i>lets</i> .
The wine of Blood, Sang des Suisses	Bale	{ A good wine, called also the Hospital and Cemetery of St. James.
Erlach.....	Berne	} Remarkable for durability.
Valteline.....	{ Made in the }	
Boudry and Cortaillods.....	Valtelline }	} Equal to third class Burgundy.
Cully.....	Nenfchâtel }	
Désalés.....	{ Near Lansanne, }	} Like Rhenish.
La Cote.....	and Vevay }	
Bernang.....	{ Between }	} Dry wines.
Frangy and Monnetier.....	Lausanne and }	
La Marque.....	Coppet }	} Tolerable of the country.
Coquempin.....	St. Gall }	
Chiavenna.....	Geneva }	} Red and white, and muscadine of tolerable quality.
	Martigny }	
	Grisons }	Aromatic, white, from red grapes.

SECOND AND THIRD CLASSES.

PORTUGUESE.

Wines.	Place.	Character.
Carcavellos, or Lisbon.....	{ Between Oëiras } and Carcavellos }	Sweetish, white, well known in England.
Bucellas.....	Near Lisbon	{ A fiery wine, from brandy being mixed with it; something like Barsac when pure.
Vinho de Terro.....	Estremadura	A light ordinary wine of the country.
Sctnval.....	"	Two kinds, dry and muscadine; both good.
Lamego.....	Near Coimbra	An inferior kind of Bordeaux.
Alenquer, Monção.....	Estremadura	As the former, but somewhat better in quality.
Santorin.....	Near Lisbon	An ordinary wine.
Barra a Barra.....	Near Lavradio	A good wine.
Colares.....	Near Cintra	A light port, of good quality.
Pezo da Regoa, Abasas, Villarinho } des Freires, Gorvaens, Alvacoës, } do Corgo, Hormida, Guials, Con- } velinhas, Galafura, Lavradio... }	Mostly on the Douro	{ Port wines of the Douro, of the first and second qualities, denominated Feitoria and Ramo.

SECOND AND THIRD CLASSES.

ITALIAN AND SICILIAN.

Wines.	Place.	Character.
Lacryma Christi	Naples, Mt. Vesuvius	Red rich muscadine, of a fine flavor and perfume.
Syracuse	Sicily	Luscious red muscadine.
Reggio	Naples	Resembling Burgundy.
Baia	"	Ordinary wine.
Mascoli	Sicily, Mt. Etna	{ The best red wines in the island, of excellent body, like the secondary Rhone growths; rare in the island.
Mascoli Sciarra		
Mascoli Macchia		
Mascoli San Giovanni		
Catania	"	Pitchy taste, ordinary wine.
Tormina and Faro	"	Tolerably good.
Ovièto	Roman States	Excellent durable red wines.
Asti	Piedmont	Ditto.
Bianillo and Aleatico	Elba	Good wine of the second class.
Bischillato	"	A durable wine, exports well.
Procanico	"	A <i>mousseux</i> wine.
Chianti	Tuscany	A good wine.
Aleatico	"	{ Resembling the Tinto of Alicante in flavor and bouquet.
Carmignano, Antella, Artimino, } Tizzana, Mentali, Lamporecchio, } Monte Spertoli, Poncina, Glogoli }	"	Good wines of the country.
Val di Marini	"	Ditto.
Naples muscadine	{ Mt. Vesuvius } Lake Averno } Maria de Capona }	A delicate fine colored wine.
Vino Greco	"	An excellent muscadine.
Carigliano	Naples	Muscadine, flavor of fennel.
Bari and Tarento	"	Muscadine and common.
Reggio	"	<i>Vin de liqueur</i> .
Baia	"	Good ordinary wine.
Gierace	Near Reggio	Between light French wine and <i>vin cuit</i> .
Asprino	Campagna	A <i>vin de mousseux</i> .
Fundi	Kingdom of Naples	Good ordinary wine.
Val di Mazara { Mazara... } { Veterano... } { Corigliani... } { Termini... } { Girgenti... }	Sicily	Of tolerable quality.
Messina, Milazzo, Avola, Vittoria ..	"	Ditto.
Lipari and Stromboli	Lipari Isles	Ordinary wines, and superior muscadine.
Imola	Near Bologna	<i>Vin cuit</i> and <i>mousseux</i> .
Terni	Near Spoleto	Good wines.
Farnese	Near Castri	Good muscadine.
Ovièto (white)	Roman States	Muscadine, not durable.
Monte Fiascone	{ Near the Lago } Bolsena }	{ A strong muscadine, finely perfumed and flavored; of great strength.
Albano	Roman States	Ditto, excellent.
Moscatoello	"	{ <i>Vins de liqueur</i> , of greater or less merit; not bearing exportation.
Aleatico	"	
Vino Santo	"	{ <i>Vins de liqueur</i> , of greater or less merit; not bearing exportation.
Vernaccia	"	
Riccia	"	Good wine, but a small quantity made.
Buti	Plain of Pisa	Weak wine.
Monte Pulciano	Tuscany	The most esteemed of the Tuscan muscadines.
Montalcino, Rimencze, Pont-Ecole } and Santo Stephano	"	Good muscadines.
Vermut	Elba	A cordial wine, prepared with wormwood, &c.
Rio	"	Good muscadine.
Vino Morto	The Veronese	Deficient in spirit and strength.
Vino Santo	"	Good red and white wines.
Bellagio	Lake of Como	Wines of color and spirit.
Labusca	Mantua	An agreeable wine.
Pavia	Pavia	Both dry and <i>mousseux</i> , but very inferior wines.
Monte di Brianza	Milan	Good flavored wines.
Panocchia, Vigatto, Traversetolo, } Casola, Avola, Azano	Parma	Ordinary wines of the country.
Val Idone, Bottola, Ponté d'Al- } lolio, Verdetto, Sala del Christo }	Placentia	Ditto.
Creta	"	"
Santo Prctasso, Frescale, Caselle, } Lassurasco, Rugarolo, Castellina, } Salso, Maggiore, Villa-Chiara, } Claretto, Puzolo	District of Borgo Placentia	{ Inferior wines, some of them <i>vins de liqueur</i> , having a disagreeable taste of honey.
Raterra and Sapolo	Modena	Ordinary wine, for home consumption.
Vin Piccolit	Friuli	Resembling Tokay.

SECOND AND THIRD CLASSES.

HUNGARIAN, AUSTRIAN, AND SCLAVONIAN.

Wines.	Place	Character.
Tokay, Essence, and Ausbruch	{ Near Mt. Tokay, } Hungary	See wines of first class.
Tokay, Maslas	"	A secondary Tokay.
Gyængyæsch	{ Mount Matra, } Upper Hungary	Wines, both red and white, much esteemed.
Edenbourg	Lower Hungary	Ditto.
Meneser	District of Arad	Red, much esteemed for spirit and sweetness.
Meneser-Ausbruch	"	{ Like Tokay, preferred by some; rich, aromatic, sweet, not cloying.
Erlon	Upper Hungary	Good red and white wines, and an Ausbruch.
Rusth	Lower Hungary	Similar to Edenbourg.
St. Gyorgy	Near Presburg	{ A white wine of excellent quality, somewhat in aroma like Tokay.
Ofen	Near Pesth	Good wine of the country.
Carlowitz	{ On the Danube, } in Sclavonia	Resembles Cote Rotie.
Buda	Near the ancient capital	Like Burgundy.
Sexard	{ Between Buda } and Esseh	{ Resembles Languedoc, a good red wine of the country.
Gros Warden	{ Near Transylva- } nia, the fortress	Ditto.
Schiller	In Sirmian	Strong and sweet, of a red color.
Wermuth { Palunia	"	Wines prepared with spices and wormwood.
{ Tropfwermuth		
Glodova, Menos, Gyordk, Paulis	Menes	Scarcely different from Meneser.
Modeon	Near Presburg	Excellent wine, resembling Burgundy.
Katschdorf, Grunau, Obernussdorf . .	"	Ditto.
Neustod, Zscheibæ, Kosrad	Near Buda	{ Wines like Burgundy and Bordeaux.
Wersitz	In the Bannat	
Jobbagy, Etsey, Sotvesch	Bannat of Tameswar	Good red wine.
Weisskirchen	"	Ditto.
Zips, Arva, Liplow	Croatia	White wine.
Buokwetz	"	Ditto; same quality.
Vinitza, Toeplitz	Transylvania	Wine of the country, Ausbruch.
Birahnan	Sebenico, Dalmatia	A wine highly characterized; not the <i>liqueur</i> .
Marachina	Moldavia	Green in color, and strong as brandy.
Cotnar	Wallachia	Light, rivalling Tokay.
Piatra	Ragusa	Good country wine.
Gravosa	Sclavonia	Good red wine.
Semlin	"	{ Both red, and of agreeable flavor, and much spirit.
Syrmia and Posega		
Podskalchi	{ Circle of Leut- } meritz, Bohemia	Red wines, which will not keep.
Melnick	Circle of Bunzlow	Ditto, like Burgundy.
Poleschowitz	Moravia	Good wines, equal to Hungarian.
Mount Calenberg	Austria	Ordinary wine.
Hoefflein, Kloster Newbourg, } Unter Kutzendorf, Kaplenburg, } Misdorf, Salnendorf, and Lich- } tenstein	"	{ Wines of little note, generally of a green hue, and drank young.
Giberwein	{ Southerly, near } Vienna	{ A wine that will keep, though of no extraordi- nary quality.
Spitz	"	Good wine.
Luttenberg	Lower Styria	Good wines, red and white.
Radskersbourg, Arnfels, Windisch, } Gonowitz, Kerchenberg	"	Of the next rank to the foregoing.
Sansal, Leitschach, Pickerne, Stadl- } berg, Pulsgau, Sauritsch, Raen, } Rast, Peittersberg, Wiesel	"	Good wines of the country.
Moettling, Weinitz	Carinthia	Resembling good Italian wines.
Freyenthurn, Wipach, Tsche- } remble, Marzamin	"	Ditto.
Proseco Antignana, St. Serf Trieste	Istria	Red and white, sparkling and well flavored.
Berchetz	An Adriatic island	Red wine, deep colored and sweet.
St. Patronio, Petit Tokai, St. } Thomas, &c.	{ At Capo d'Istria, } Pirano, and Cittanova	Good <i>vins de liqueur</i> .
Corregliano	Istria	A good wine, consumed at Venice.
Ieszgard	In the Tolna district	A superior red wine.

SECOND AND THIRD CLASSES.—SPANISH.

Wines.	Place	Character.
Val de Peñas	New Castile	Good body, deeper than Bordeaux in color.
Manzanares	Manzanares	An inferior Val de Peñas
Ciudad Real	New Castile	A tolerable red wine.
Albacete	"	Ditto.
Vino Tinto, Alicant	Valencia	Yellowish red color, when old called Fondello.
Mataro	Catalonia	Good bodied and generous.
Torre. Beni Carlos, Santo Domingo, } Segorbe, Perales, Vineroz. }	Valencia	{ Wines of good body, some of the most esteemed red growths of the country; color deep.
Hospital	Arragon	{ Excellent flavor and body, from the Garnacho grape.
Carignena	"	A vino tinto from the same fruit.
Tinto Olivencia	Estremadura	Excellent red wine, the best in Spain.
Tinto di Rota, or Tintilla	Andalusia	A sweet reddish cordial wine.
Ribidavia	Gallicia	An ordinary red wine.
Chacoli	Biscay	A very harsh austere wine.
Guindre	Malaga	Dark, flavored with cherries.
Tinto di Malaga	"	Seldom exported, a good wine.
Aleyor	{ Minorea, near } Mount Taurus }	A red wine, consumed on the island.
Palma	Majorca	A full-bodied wine.
Cordova	Andalusia	{ Good red wines of the country.
Mirando de Ebro	Old Castile	
Carbezon	Valladolid	{ A luscious sweet wine.
Terra del Campo	Old Castile	
Velez Malaga	Malaga	A luscious sweet wine, with a burnt taste.
Malaga	"	A luscious sweet wine, fine and delicate.
Pedro Ximenes	"	Resembling sherry, dry.
Malaga Xeres	"	Pale and brown sherry.
Xeres vino seco, pale and brown.	Xeres de la Frontera	A second growth sherry.
Abocado	"	A yellowish-white wine.
Huesca	"	{ A sweet wine, of light amber color.
Paxarete	{ Frontera and } St. Lucar }	
Moguer	Niebla, Andalusia	{ Used to lower the sherries at Xeres, of which it is an inferior species.
Negro Rancio	Rota	A sweet wine, of a yellow color.
Montilla	Cordova	A dry wine, of good bouquet and flavor.
Borja	{ Arragon and } Tarragona }	A luscious wine.
San Lucar di Barameda	Audalusia	A light red muscadine.
Manzanilla	"	Dry white, of inferior quality : a <i>vin du pays</i> .
Zalonge and Carlon	"	Ditto.
Yepes	New Castile	A well-flavored wine.
Fuenceral	"	A <i>vin de liqueur</i> .
Sitges and the Priory	Catalonia	Malmseys of two qualities.
Peralta and Tudela	Navarre	{ White dessert wines. Peralta is a Rancio when aged.
Pollentia	Majorca	A <i>vin de liqueur</i> .
Alba Flora	Minorea	A dry kind of Rhenish.
Vidonia	The Canaries	A wine resembling Madeira, of inferior quality.
Verdoua	"	A green wine, not now made.
Palma	"	A rich Malmsey, having a taste of the pine apple.

MADEIRA AND THE AZORES.

Wines	Place.	Character.
Malvasia, or Malmsey	Madeira	Rich and sweet.
Madeira	"	A durable, dry wine.
Sercial	"	Ditto, of excellent quality.
Muscatel	"	Not exported : a good wine.
Tinto	"	{ A red wine, changing in twenty years to rich old Madeira in color.
Figaa do Pereiro	"	{ Of inferior kind to the above.
Santo Antonio	"	
Vino Passado	Pico, in the Azores	A species of Malmsey, of light quality; keeps ill.
Vino Seco	"	A dry wine, light, not durable.

DOMESTIC WINES.—The grape ripens too seldom in England to be applied with advantage to the making of wine. The warmth of September is not sufficient to mature the grape; though up to some time in August, and generally to the end of that month, the vine may progress favorably. There are many fruits, however,

from which very palatable household wines can be made, and from which dull wines are continually manufactured, when those more lively can be introduced from the produce of the orchards, gardens, and fields of England. The mode of making these wines is generally not well understood; if it were, the wines would be much more palatable. Yeast, resorted to for the purpose of fermentation, often imparts a nauseous after-taste to the wine, which would ferment well enough in the natural way. There is nothing unwholesome in these wines, if properly made; and to this end the wine of the grape, and its mode of management, should be clearly comprehended, that its principles may be made applicable to domestic wine manufacture. The malic acid in the wines of English fruit often causes a trifling inconvenience to the *primæ viæ*, which acid may easily be exterminated in making the wine. The wine of the grape should be the model after which all wine of the garden-growth should be fermented—general principles should be first mastered. Suppose the gooseberry be taken as the fruit, it contains centesimally:—

	Unripe.	Ripe.
Green coloring matter,.....	0.03	—
Sugar,	0.52	6.24
Gum,	1.36	0.78
Albumen,	1.07	0.87
Malic acid,	1.80	2.41
Citric acid,	0.12	0.30
Lime,	0.24	0.29
Lignin, with seeds,	8.45	8.01
Water,.....	86.41	81.10
	100.00	100.00

The above are all the requisites for making wine, and some that are to be dispensed with; a deficiency in tartar is often noticed, but this can be supplied artificially. The excess of malic acid, on the other hand, is injurious; but as in making white wines in the South of Spain, this acid is got rid of by sprinkling powdered gypsum over the grapes, which takes it up, the same means should be adopted when making domestic wines in England.

Sugar is the first constituent in wine-making, and as it does not abound in some garden-fruits in England, it must be added. Cane-sugar, it has been seen, differs from grape-sugar in its proportional parts, but it is converted into grape-sugar by the process of fermentation. It is a sugar which goes slower into fermentation than that of the grape, and the alcohol in the wine always bears a proportion to the pre-existent sugar. This sugar uniformly contains a portion of a vegetal extractive matter, unless it is separated from it by art. The natural sugar of some plants also contains, some more, others less, of this sweet vegetal matter. If there is much of it in the sugar, the wine will be dry and perfect, because all the sugar will have been changed into alcohol. The mucilage, or vegetal extractive matter, like the gluten of wheat or albumen, contains azote, the gas of which has been noticed in grape wine making. This matter, found too in yeast, thus acts in exciting fermentation. Most garden fruits possess it; and it is this sweet principle combined with that in sugar, which operates the conversion with other wine, as with the grape. Water is another constituent. As to

the other substances, except tartar, they rather concern the curious in chemistry than the maker of family wines, for some can only be detected by the close scrutiny of the experienced chemist. Little color can be communicated to any of our domestic wines, if the elderberry, currant, blackberry, and black cherry be excepted; but this is a matter of little moment in that which should rather be adopted to please the palate than the eye. If astringency or roughness be in request, that loss may be innocently supplied by the application of catechu. The damson and sloe alone possess it naturally.

The substances necessary to vinous fermentation, the sugar and its sweet principle, the natural vegetal extract, the tartaric acid—in place of which latter the malic acid is often found, which should be dispensed with, and tartar added artificially—and water; these in certain preparations, and in their differences, are the essentials in this class of wines. Sugar is the most important, and its decomposition gives out the alcohol, on which the strength of the wine depends; therefore its quality is of great importance. When the sweet principle and sugar—for they are in union—have disappeared in fermentation, and there is no more vegetal extractive matter belonging to the fruit in the liquid, the wine is a dry wine, and is in its perfect state. If the sugar be in excess, the result is wine and sugar; vulgarly, a sweet wine. If the vegetal extract be in excess, and the fermentation too prolonged, acetic acid will be the product.

The want of attention to the foregoing points often renders the making of dry wines a failure. No yeast should ever be used. If the vegetal extractive matter be wanting, the lees of other wine may be tried; but this is seldom needful, with due care. During fermentation the leaven or ferment is insoluble, and rises to the surface, or falls to the bottom. On restoring this to the surface, the fermentation may be prolonged at pleasure, until the necessary dryness be gained. To attain a sweet wine, the fermentation should be stayed by separating the wine from the ferment, and fusing it with isinglass or white of egg. Thus the ferment is separated, and the operation suspended; it may be renewed by restoring the separated matter; if not, a sweet wine remains. It cannot run into acetous fermentation if its leaven be expended; but still there is hazard, and some care necessary, in thus renewing the operation.

Of these acids, sometimes found in fruits—the tartaric, malic, and oxalic—only the first two have any share in the fermentation. Tartar abounds in the grape, and to that its superiority is ascribed. It is wanting in our domestic fruits, or very scantily bestowed. Malic acid is predominant in apples and pears, and they give liquors very different from wine. Crude tartar is best added to the must for domestic wines, not the purified salt.

Care should be taken not to carry on fermentation in new wooden vessels, nor to place wine in them without due preparation. The vegetal extract in the wood will infallibly set the fluid in fermentation, as is well known to the French wine-grower.

The end of the fermentation is the production of the alcohol; and the chemical action involved is well

understood, although the primary force of the ferment is not, nor can it be, so well comprehended. In this respect Nature eludes the efforts of the chemist and physiologist to define correctly her workings, or submit a true definition of the affinities which are continually set in motion by natural force. As regards fermentation, it is true that only the salient points of the chemical changes are understood, but they are sufficient to govern the industry of the fermentation of liquids of every kind, provided all that chemistry has revealed be known to the operator. In domestic wines no just rule has been regarded. Most of the directions are based upon false principles, and display extraordinary ignorance, according to Dr. McCulloch, who has written so well upon the subject; and if not clear to the family makers of such wines, and too scientific for the common concoctors of them, his work still is not the less worthy because the stolid do not perceive its merits.

BRANDE made analyses of the strength of some of the domestic wines, which are appended. The alcoholic strength was per cent. at eighty-nine alcohol and eleven water.

Wines.	Per cent.	Wines.	Per cent.
Grape,	18.11	Orange,	11.26
Raisin,	26.40	Elder,	8.79
Do.	25.27	Mead,	7.32
Do.	23.20	Cider,	9.87
Do. average, ..	25.12	Do.	5.21
Currant,	20.55	Do. average, ..	7.54
Gooseberry, ..	11.84	Perry, average, ..	7.26

Before going into the practical part of the subject, the warning against the use of yeast must be repeated. It is a vile substance when in contact with anything vinous, imparting a base flavor, and is to be altogether shunned. The regulation of the temperature, too, is to be sedulously regarded, that the fermentative process may not proceed too rapidly. The bulk of the must to be fermented, and its exact quality must be well considered; the addition of flavoring substances, and finally, the proper vessels adopted for the different operations.

The fruits most commonly employed for making domestic wines are the elderberry, cherry, raspberry, sloe, damson, quince, strawberry, mulberry, gooseberry, lemon, orange, and two or three kinds of currants. Of these several do not retain their flavor, and are to be rejected on that account. The flavor of the strawberry is not communicated to the wine, nor of the quince or raspberry. These might be infused to advantage nearly at the close of the fermentation of some tasteless must, and thus their flavor be sustained in the wine. The blackberry and mulberry should, as in the instance of grape-wine, be allowed to go into fermentation, skins and all, for the sake of the color. The damson and sloe make a good rough wine, but care must be taken to proportion the sugar to the fruit as to quantity, and by protracting the fermentation, to make a dry wine. By a due admixture of elderberries or currants with sloes and damsons, wines like inferior ports are often easily produced. The proportions vary according to the season. The elderberry may be made to yield an excellent red wine. It possesses enough of the extractive principle to impart a very rich tint, and even a

fine deep color. Tartar should be introduced into the must; and, besides, this berry requires much sugar, as the saccharine principle is scanty.

The gooseberry is known as giving a species of champagne to the list of domestic wines, which are made to effervesce; but, in order to answer, the gooseberries are used in an unripe state. The effervescing property always results from the use of unripe fruit, and will be readily produced by mixing ripe and unripe grapes together; and it is the same with the gooseberry. In general the flavor is bad, and to avoid it, as it is imparted by the ripe fruit, the more unripe should be prepared. This wine should be made with the expressed juice of the fruit alone, and nothing else should be fermented, the skins not being suffered in the must. By this means any disagreeable or peculiar taste is avoided, and the wine, if nearly tasteless, is brisk, pleasant, and perfectly free from any bad flavor. To make this wine, three pounds of sugar, and four of fruit, are allowed to eight pounds of water. Five pounds of fruit would be better, to avoid sweetness, though in complete fermentation; the wine would then be amply strong. No brandy should be added to effervescing wines. Care should be taken in bottling, and the same attention bestowed upon genuine champagne should be bestowed on this imitation wine, which will readily repay the extra trouble. This wine arrives at perfection only in the cellar. Wine made from ripe gooseberries is good for little; but if attempted, the skins must be carefully excluded.

In such wines too little fruit in proportion is used. In currant wines the fruit is always stinted, there being sufficient extractive matter and natural acid to insure, if rightly arranged, a very perfect fermentation. These wines are made too sweet, and pall upon the palate. The proportion adopted is in all cases to be increased as regards the fruit, and the skins to be excluded from the must. The recipes, so manifold, handed about for domestic wines, continually show that the true principles of making such wines are not recognized, although laid down so lucidly by Dr. McCulloch. British champagne is directed to be made by crushing the fruit with a mallet, and a gallon of fruit is to be put to a gallon of water; then brandy is added, and sugar of the species often to be avoided; and brandy is added again in bottling. McCulloch recommends boiling the fruit, in some cases, previous to fermentation. The black currant acquires, by boiling, an agreeable flavor. The success of the plan is remarkable; the more so as, in its natural state and unboiled, it is harsh. The wine made from it much resembles sweet Cape wine. The same improvement takes place in regard to the red and white currant. The boiling should not be protracted. It is always best to boil about a third of the quantity used, and to apply the rest in the natural state. The boiling must not be continued too long, because it tends to precipitate the ferment.

The dried raisin is largely used in making domestic wines; and it naturally must be analogous in some respect to certain foreign wines, because for making them the grapes are not used until they are shrivelled in the sun. Thick, sweet grape-wines are made this way. The process adopted in making raisin-wine in

England has not shown any approach, with the same materials, to the wines made of dry raisins, or such as are called *straw wines*, or some of those of Malaga. In the mode actually adopted here, whether for domestic use, or for the deceptive objects of wine-dealers to mingle with foreign wines, from two to seven pounds of raisins are employed to a gallon of water, common elayed sugar or molasses from half a pound to three or four pounds, and oftentimes from four to six pounds of tartar in the crude state are added. Yeast is not used; still the wine is never well-tasted, and to obviate that, as the bad taste may arise from the skins, cold water is used. It is necessary to apportion the sugar to the tartar. From two to four per cent. of crude tartar is a sufficient addition, giving more when the fruit is sweetest. In regard to the sugar, two pounds to the gallon of the other ingredients will produce a light wine like the white wine of Bordeaux. Three pounds will give the body of hermitage, and four that of Muscat or of Cape Madeira, before their respective doses of brandy were added to them. The sugar added must be apportioned to the quantity in the fruit. If the wine is to be a sweet wine, not less than four pounds to the gallon must be used. The water added must not be out of all proportion to the fruit—which last rarely forms a fourth of the entire fluid—and four pounds to eight of water, and three or four of sugar, supposing no regard is had to the state of the fruit in respect to its ripeness. The vegetal extractive matter in such a case is deficient, as well as the native acid, and this acts injuriously upon the fermentation, and renders it inefficient; the must, consisting of an overplus of sugar and water, cannot thus form wine. Let the principle wanted be increased, and the wine will put on the true character—the dilution of the acid, if the fruit be ripe; and if it be unripe, then the acid and extract being in excess, the operation must fail of fulfilling expectation.

Flavor may be easily imparted to all those wines which want it. Elderflowers, mignonette, clove pinks, for example—or sweet briar, wormwood, ginger, cloves, orris, and the like—will impart, either of them, or perhaps some in combination, a flavor agreeable to the taste of the maker. They are suspended in a bag from the bung-hole during the first stage of fermentation. To please the eye, elderberries, or mulberries, will supply color, or what the French call *vin de fismes*—a color liquor, made near Rheims of a small bitter cherry used for the same purpose, a few drops being sufficient to color a bottle. In Holland, tounsel is used for the same purpose—the *crotum tinctorium* of Linnæus. It is naturally of a blue color, but on coming into contact with an acid it immediately takes a red hue. In France it is said that color derived from woods, as Brazil or logwood, do not long resist the acid of the wines; and, therefore, they find it better to darken the light hue of wines by mingling deep-colored wine with them. This, however, need not deter from the use of such means to suit the eye in domestic wines of English fruit. Bitterness may be obtained by the use of burnt sugar, as well as yellow tints. Cognac brandy for the English market is thus colored in France, where the people use the pale spirit.

All vinous operations require great care and sound

judgment. In fining home-made wines, the same management is necessary as in treating the grape-juice with a similar object. The imitation wines made in the household must first be considered in regard to the model immediately in view. If the object be a sweet wine, of which the fermentation is incomplete from the want of sugar in the must, or if its suspension be by design as before described, the operation to be followed is clear.

If the wine be designed to sparkle or effervesce, the cause and mode of acting has been shown; and that briskness is not much in accordance with sweetness. Though generally made of the gooseberry, any other fruit in a proper state of immaturity will answer as well. The use of carbonate of potassa or soda must be avoided, because the gas is almost all disengaged in the first glass on pouring out, before the wine can be drunk, nor has it anything like the effect of carbonic acid gas in the wine. It also deteriorates the taste, and destroys the native acid, replacing it with an alkali.

The Rhenish wines have never been successfully imitated, and for the paramount reason, that their constituent parts are so accurately balanced that they would require great judgment, and much care, in the process; the fermentation must be perfect, and exact proportions be carefully kept in the ingredients. Even then their preservation would require great attention. Fining, racking, and sulphuring, must be had recourse to by hands often not adepts in their use. The dry wines of some strength, imitative of Sherry and Madeira, may be made strong enough without the addition of brandy, which, however, may be added to them by the operator, if he sees it requisite.

Dr. McCulloch recommended that wine should be made from grapes grown in England. The grapes may not ripen in some years, and in an agricultural view it is profitless; but wine is continually made by cottagers in Sussex from the grapes grown in front of their houses, and some species ripen a full month before others. The white muscadine, the two varieties of the chasselas, the black Hamburg, and others, are of this class. But to make domestic wine from the grape in England, does not demand that the grape should reach the maturity required for its wines, as the term is generally understood. A crop of grapes is certain, if not always a ripe crop. A compound artificial must can be made from the admixture of sugar with the extractive and other matter of the fruit, which, undergoing a regular fermentation, forms a perfect wine, as applicable to the grape as the gooseberry. The experiment has been tried and found successful, and domestic wines made this way declared excellent. Three pounds, or less, of sugar to the gallon, with the hardiest grapes, produce a wine of the strength of red hermitage, not void of flavor, but the reverse. Dr. McCulloch mentions the proportions he found needful, both of sugar, water, and other substances necessary for the purpose. He kept some of the wines twenty years, and found them as little liable to destruction as the wines of France.

The want of judgment, the haste, the non-comprehension of the chemical principles upon which wine is made from domestic fruits, the want sometimes of a clean palate on the part of the maker, and the aban-

donment of a nice operation to the hands of servants and old housewives, have caused great mistakes in the manipulation of these wines. Dry wines of the first quality do not require that maturity of the grape which is so necessary to those which are sweet. In the first ease sugar can be added; but the eustomary notion of the ignorant in this, as in other eases, often prevails, and the neglect of the green grape for the green gooseberry is a striking proof of it. Nor is this all; for it has been proved by ehemieal examination, that the tendrils, shoots, and even the leaves of the vine themselves, possess exactly the same qualities as the erude fruit. Experiments were in consequence instituted in France, to try if they would not answer for the purpose, and they were satisfactory; but there, where the fruit was to be had in any state, the matter naturally terminated; while in England it was different. The suecess of the attempt was decisive, on adopting the management had recourse to in treating wine from other unripe fruit. Only young or half-green vine leaves are selected, together with the tendrils. The old leaves are not proper. The month of June is the right season to pluck them. The vines for the purpose may be planted anywhere, and suffered to run up unpruned. Close imitations of the sparkling wines of Champagne and of St. Peray have been made this way, and none were made that were not as good as the ordinary sweet wines of the Cape. If the wine is too sweet from want of the vegetable extract in a suffieient quantity, a fresh infusion will reinstate the fermentation. The wine of a defective year in goodness, may be renewed tho next season. The leaves should be infused sometime before they are used, yielding their virtues more readily to hot than eold water without any material difference in the result. Half a pound of erude tartar, or more, within a pound, to two gallons of must, is useful. The expense of the sugar here is nearly the whole ineurred, and a single vine will supply a family, as the leaves are snecessive.

A few specifie direetions under the seientifie authority before mentioned:—The eask measure being supposed ten gallons, will illustrate the foregoing principles; those adapted to the lands of the vine being kept in view as guides, where any diffieulty may ooeur. In a tub or vat earefully eleaned, that has a eapaeity for fifteen or twenty gallons, forty pounds of the gooseberry of the green Bath kind are introdneed, avoiding any that are ripe. Rejeet the unsound, and remove the blossom and fruit-stalk, or their remains. The small berries may be separated by a sieve. The fruit is to be bruised into the vat by a pressure sufficient to break the skins, without fraeturing the seeds or eompressing it too much. Four gallons of water are then poured in upon the fruit, and tho whole is earefully stirred and eompressed with tho hand, until the juiee and pulp are separated from the solid matter. The materials must rest for ten or twenty-four hours, and then be strained through a eoarse bag with as much foree as can be easily applied. A gallon of fresh water is to be added to the mash, to remove any soluble matter remaining. From twenty-five to thirty pounds of white sugar are to be dissolved in the must

or juiee thus obtained, and the mass of fluid increased by more water to ten gallons and a-half. This difference in the weight of the sugar is to balance any in the quality of the fruit, the discovery of which difference must depend upon the judgment of the operator. Old haphazard receipts gave forty pounds of sugar, which of eourse make a sweet wine, continually failing in effervescence on that account. The must is next to be plaeced in a tub or vat, over which a blanket is thrown, and a board over that, and the whole kept in a temperature between 55° and 60°, to remain from twelve to twenty-four hours, according to the state of the fermentative proecess. It is then to be drawn off into a cask until the fluid nearly reaches the bung-hole, so that the seum which aseends to the surface may overflow, and be thrown out. As the fermentation goes on, and the bulk of the liquid diminishes in the eask, the superfluous must made for that purpose must be poured in, so as to keep the liquid always near the bung-hole. When the fermentation diminishes still more, which may be judged of by the reduction of the hissing sound, the bung is driven in, and a hole bored on one side of it, into which a wooden peg is put, and in a day or two taken out, in order that the gas within may have vent. It is then restored and reopened to let the gas again escape, until, there being no longer any danger from the expansion, it is tightened for good. The wine is to be kept over the next winter season, in a eool eellar, and on a elear sharp day about the beginning of Mareh, if fine, it is bottled; if not fine, or to insure its fineness, if doubted, at the end of Deeember it is deeanted into a fresh elean cask, to free it from the lees, which, if the wine be too sweet, instead of drawing it off, should then be stirred up in it, inecreasing the temperature to renew the fermentation. When drawn off, it is fined with isinglass; and if not elear, the operation is repeated in dry, elear, eold weather as before, and bottled in Mareh, and not later. Such a wine is brisk like champagne, and similar in quality, but stronger, differing in little but the flavor. Sometimes the wine will be still, like sillery, or sweet, without elose attention to the proecess; at other times it will be dry. If sweet and still, it may be remanufactured the next season by renewing the fermentation, and repeating, under the addition of fresh juiee or must, the former treatment. If it be dry, it remains so, and may be drawn off into a sulphured cask, and then fined and bottled. Any peeuliar and not agreeable taste, during the first year, will go off by age. Sueh wines are best when drunk at five or six years old. In making the foregoing wine, the mode in managing grapo-wine—fermenting the husks or skins as well as the juiee with the sugar—may, on the other hand, be adopted in the earlier stage of the operation. The rapidity of the fermentation in this way is much ineincreased; the wine, stronger and less sweet, will gain more flavor. Crude tartar, to the extent of six ounces to the ten gallons, is sometimes added. Sweetness with briskness, though the latter quality is hazarded, may be had by using sugar to a greater extent under forty pounds. Brisk domestic wines are not durable nor strong, and must be drunk very early from want of the eapaeity for keeping. Effervescence without sweetness

is obtained by increasing the fruit, as in the proportion of fifty pounds of fruit to thirty of sugar.

The wine made from unripe currants, under the same general process as the former, requires that the stalks be separated with care. The must of this fruit is much easier to manage than that of the gooseberry, and it is far better calculated for brisk wine, and less likely to carry a bad flavor.

Nothing but the pure must is introduced into the cask—not a particle of the mash. If, in the fermenting in the vat, the scum, crest, or head, called the *chapeau* by the French, be tainted with sourness or mustiness, it must be at once removed; and when the fermentation of the mash does not take place with the must, the latter may be at once introduced into the cask.

Mature gooseberries and currants are made to produce dry and sweet wines by the foregoing modes. In sweet wines the fruit should not be above forty pounds; if in dry, it should be carried to sixty. The sugar should be full thirty pounds, unless a strong wine is desired, when forty pounds must be employed.

Wines from elderberries are made with the same proportions of ingredients as the former kinds, and in the same manner. If boiled fruit is taken—an operation which relates almost wholly to the black currant—the fruit must only be brought to the boiling point of the water, and the burning of it at the bottom of the vessel must be guarded against. Wine from the mature grape in this country it is not worth while to manufacture, as too few grapes ripen to make it any other than an object of curiosity, and the mode of treatment of them, described in the preceding pages, contains all that is necessary upon the subject.

It is probably due to M'CULLOCH that it was ever known that domestic wines could be made from immature grapes, vine tendrils, the young leaves, and the thinnings of the branches in places where vines are grown under shelter, in different stages towards maturity, no matter how different in species. No part of the vine need be feared as communicating a bad flavor. If the immature grapes be those grown in the open air, they should be taken just at their first tendency to ripen. The proportions and treatment are similar to those recommended for the gooseberry, but the husks may always be fermented in the vat with the must. Except in not breaking the seeds, no care need be taken about not bruising the fruit. The fermentation will be slow; but no obnoxious yeast is to be employed. Patience is necessary, but the operation will not ultimately be less effectual. Elevation of the temperature will excite it, if languid; as will also agitation of the cask, or omitting to replenish the fluid at the bung, so that the scum may remain upon the liquor.

The wine made from the young leaves, tendrils, and even young shoots, may be taken at any period from vines cultivated for this object, from which fruit is not expected. If the claret vine—*Clairette rouge de l'Herault*—be cultivated for the purpose, the wine will be of a red color. The leaves should be young, and sixty or eighty pounds should be introduced into a vat. In the vicinity of a large town they should be first washed, to clear them of sooty particles from the impure atmosphere. Seven or eight gallons of boiling water

should then be poured upon them, and left to infuse for twenty-four hours. The water being poured off, the leaves are pressed in a press of considerable power, washed with an additional gallon of water, and again pressed. Sugar, from twenty-five to thirty pounds, is then to be added to the mixed liquors, and the whole made up to ten gallons and a half, when the same process is to be pursued as in the case of gooseberry wine. The water soon cools down to the usual temperature, it being used hot in order more effectually to extract the soluble part of the plant or fruit. These proportions are for brisk wines, which, if mismanaged, will fail of due effect. In the case of sweet wines of the same substances, from thirty-five to forty pounds of sugar must be used. As soon as the first fermentation has subsided, the wine is racked into a sulphured cask and fined. If it tend to a renewal of the fermentation, it must be racked and fined again, and even a third time. When perfected, the wine may remain in the cask as long as is desired. For dry wines the proportion of fruit to the sugar is to be the largest of all. The bung must be left open, and the fermentation, if sluggish, must be increased by heat and agitation. If the wine continues too sweet, it may be bunged down until the next spring without fining, and then the fermentation must be renewed by adding fresh must. As soon as it has become sufficiently dry, it must be fined into a sulphured cask, and again fined before bottling. The dry and sweet wines of this kind should be kept five years to be in their highest perfection. The brisk wines are drank after being six months in bottle, and are good to their third year. If they lose their briskness, they become dry, something like the Moselle or Rhine, and will keep indefinitely.

Wines, if they can be so called, are also made of dried substances, as ginger. They are composed of sugar and water, fermented with yeast and flavored with ginger. These are rather drinks than wine. The last are made by fermenting substances which possess little or none of their own extractive vegetal matter. Three pounds of moist sugar, a gallon of water to two ounces of bruised ginger are boiled, skimmed, and set to ferment with a yeast toast, flavored with a lemon to each gallon, or a little balm, and then bunged up. In about two months it is fit for drinking, having been fined with isinglass.

Mead, a very ancient domestic wine of honey, is made with sixty gallons of pure soft water, and seven gallons and a half of clarified honey, of which mellitose—see SUGAR, Vol. II. p. 966—is the sweet principle. In a copper of thirty gallons capacity, having mixed the honey and water, boil it down to one-fourth, then let it off, and boil the other moiety in the same manner; and when thus reduced fill up the copper with what was boiled first, and continue ebullition and filling up until the copper will contain half the liquor, all the rest having evaporated. The liquor must not be skimmed, but the scum must be well mingled with the liquor while seething, by means of a jet. When this is done it is drawn off into under-backs by a tap in the copper, and the fluid falls to the temperature of new milk. Then it is turned up and fermented in the vessel, where it forms a thick head. When it has

ceased to ferment it is closed from the air, and bottled at the end of six months, having been well worked and kept in the same cellar temperature as it had before. Aromatic flavors are often added by mixing elder or rosemary, marjoram flowers, and the like; or cinnamon, cloves, or other spices, during the process.

Raisin wine was manufactured light and dry in England of a superior kind, by Mr. AIKIN, secretary to the Society of Arts in 1829. Dr. M'CULLOCH censured the mode in which it is generally attempted to be made, and noticed the failure which is naturally to be expected from the use of molasses, coarse sugar, and the nauseous yeast of beer, which can never be rendered vinous. He would have the native acid neutralized, and with all domestic wines use crude tartar. Mr. AIKIN's wine was produced from Muscatel raisins. These, it is obvious, being sweet and dry, were not very different from some of the shrivelled and dried-up grapes with which wines are made in the South of Europe, as in the example of straw wines, for which the grapes are kept on the vine till shrivelled, and then further dried upon straw, giving a thick must, scanty in proportion to the produce, in a state of the grape so over-mature. Muscatel raisins are imported in boxes of twenty pounds weight. The fruit kept in the warehouse or shop unsold for above a year, is less approved by purchasers than when new, the rich pulp becoming mixed with the saccharine concretions. The extractive matter or gluten in the raisin is more than sufficient to ferment its sugar, and only from one-tenth to a third of the weight of the raisins is added. Cane sugar should be avoided in the unrefined state; if used it should be loaf. Sugar from honey or starch would be best, as unrefined sugar of the cane taints the wine. The raisins, without the stems, are chopped fine on a board, in the mode adopted with minced meat. Three pounds of raisins and one pound of sugar, were used to an ale gallon of water. The next process is mashing or maceration. If the former mode is adopted, the chopped raisins are placed in a tub, and hot water, a quart to four pounds of fruit, poured over them—the water not heated above 120°—to extract the mucilage. The whole is then stirred with the hand, no lumps being left, and placed in a sieve over a tub a short time to drain; this operation is repeated a second time throughout. The clamminess of the mass is by this extracted. The water for a third mash is poured on at 160°. The liquor now begins to be acidulous, with little sweetness. Three-fourths of the mash being made and tasted, to discover if it be sufficiently astringent, the stems or stalks, in part or all, are used, according as more or less astringency is intended. Hot water is poured upon the must, and the whole is well pressed by the hand. The three first mashes are now thrown into the tun, and the sugar, with as much of the last mash as will bring the must to its due proportion of one ale gallon to three pounds of fruit and one of sugar. The operation so far requires four or five hours; the temperature of the must is about 70°. The liquor soon ferments according to the atmospheric temperature and its treatment, but generally within thirty-six hours. The scum is either duly removed, or suffered to remain till the wine is drawn off. If the fermentation is languid, the cover is kept on the tun

and the scum stirred into the liquor; if too rapid, the cover is taken off and the scum removed as it rises. The must is thus become vinous, and is transferred to earboys, or stone-ware barrels, holding six or seven gallons. Safety tubes of glass are placed in the bungs, and on the second day an inch of quicksilver in the tube, to exclude the air. The bungs are covered with a cement consisting of wax and rosin. Carbonic gas bubbles through the quicksilver for some weeks, when it ceases. The wine should remain for the summer in the earboys, or barrels, if the latter be used. The wine thus made in April should be bottled in March, or if made in October, be bottled in September. The wine is not fined, for a light dry wine the inventor thought would be injured by being deprived of its tannin. After a year in bottle the wine had a bouquet like elderflower. As the wine is not fined it is decanted with care to keep it clear. It is of a pale yellow color, but in a short time deepens to the tint of Buellas, having a flavor something like prussic acid at uncorking, which disappears. If, in place of mashing, maceration is applied, putting the chopped raisins and sugar into cold water, a higher colored wine is obtained, the fermentation is slower, and it is destitute of the elderflower bouquet, acquiring a taste from the husks of the raisins; but often this second mode of treatment answers well. It is sometimes twenty days under fermentation. Tartar is often added in making this kind of wine, but it often fails to be good—generally from the use of molasses, cane-sugar, and yeast.

Makers of domestic wines, it must be repeated, fail from not, before commencing their attempts, becoming perfectly acquainted with the mode of making foreign grape-wine, and the principles upon which it is done, which are applicable to all domestic wines, almost without exception. They are scarcely ever what they are capable of being made. In the evidence on the wine duties, before a Committee of the House of Commons, Mr. A. WALKER and Mr. J. FRITH were examined. They deal in wine, home-made, of all kinds, and some bearing foreign names. The wholesale price by the hogshead was five shillings per gallon. They make sixty-five thousand gallons, of which ten thousand are British port and sherry. It is estimated that six hundred thousand gallons of these wines are made. Port is imitated from the black cherry; champagne from French grapes; port, partly too with French grapes and raisins; and Cape or Pontac, with bottoms of Oporto and Spanish wines. Spirit is added to them all. Some champagne, home-made, is from rhubarb and gooseberry. It is averred that any light wine may be made to pass for home-made champagne, by means of sirup and carbonic gas, applied as if to aerated waters. However this may be in practice, Dr. M'CULLOCH so well explained the process of making these wines, that success is sure wherever the guide he has left is followed; and if the domestic manufacturer be not successful, it is not for want of the soundness of the principle, but of the practical action arising from its knowledge.

WINE MEASURES.—The imperial gallon wine measure which superseded the old contains ten lbs. avoirdupois of distilled water, or 277·274 cubic inches. The old wine gallon was equal to two hundred and thirty-one

cubic inches, the ratio being nearly as six to five, or more correctly as one to 0·833111. The imperial

wine-pint is 34·65925. The old English wine measures were:—

Tun.	Pipes.	Puncheons.	Hogsheads.	Tierces.	Barrels.	Rundlets.	Gallons.	Quarts	Pints	Quarterns.	Cubic Inches
1	2	3	4	6	8	14	252	1008	2016	8064	58212·
	1	1½	2	3	4	7½	126	504	1008	4032	29106·
		1	1½	2	2½	5½	84	336	672	2688	19404·
			1	1½	2	3½	63	252	504	2016	14553·
				1	1½	2½	42	168	336	1344	9702·
					1	1½	31½	126	252	1008	7276·5
						1	18	72	144	576	4158·
							1	4	8	32	231·
								1	2	8	57·75
									1	4	28·875
										1	7·219

Wine measures differ greatly in the European wine-making countries, and give much perplexity in conducting operations of any kind in regard to them. Thus a tun is two pipes; three puncheons, four hogsheads; six tierces, two hundred and fifty-two old English gallons; and one thousand and eight quarts, two thousand and sixteen pints. The following are some of the more common measures:—

	Old Gallons.	New Gallons
Tun,.....	252	210
Pipe of Port,.....	138	115
Do. Carcavillos, Lisbon, Bucellas,.....	140	117
Do. Madeira,.....	110	92
Do. Sicilian, Marsala,.....	112	93
Do. Vidonia, Teneriffe,.....	120	100
Butt Mountain, } Do. Malaga, }	126	105
Do. Sherry,.....	120	100
Hogshead, Claret,.....	57	46
Do. Tent,.....	63	52
Ohm Rhenish,.....	36	30
Do. Aix-la-Chapelle,.....	—	35
Do. Cologne,.....	—	41
Do. Heidelberg,.....	—	29
Do. Cassel,.....	—	43
Do. Frankfort,.....	—	39

The French measures are the litre and hectolitre. The first contains 61·0280264 cubic inches; the second, 3·531714693 feet English; or the litre is equal to 2·113 pints old English wine measure, and the hectolitre to 26·4 old English gallons, or to 22·01 gallons imperial, and the litre to 4·5432. Therefore, 100 imperial gallons are 454·3200 litres. A pipe of port contains 522·3680 litres; a butt of sherry, 490·6656; a hogshead of claret, 208·9872, and an ohm of Rhenish 136·2960. In France, let the name of the cask or measure be what it may, the stranger asking the number of litres, is at once answered—the litre being the legal standard.

FRENCH WINE MEASURES WITH OLD ENGLISH.

Litres.	Cubic inches.	Imperial pints.	Old wine pints.	Oz. of water, troy.
1 =	61·028	1·7608	2·11353	31·104
2 =	122·056	3·5216	4·22706	61·208
3 =	183·084	5·2822	6·34059	96·312
4 =	244·112	7·0430	8·45412	128·416
5 =	305·140	8·8038	10·56765	160·520
6 =	366·168	10·5646	12·68118	192·624
7 =	427·196	12·3253	14·79471	224·728
8 =	488·224	14·0861	16·90824	256·832
9 =	549·252	15·8469	19·02177	288·936

In some countries a troublesome variety prevails in measures of the same name. In Sweden, the ohm is 139·019 litres, or 30·543 gallons imperial; at Strasburg it is only 46·093 litres, or 10·146 gallons.

The measures for wine in Spain are commonly arrobas, of which sixteen make a mayo; twenty-seven mayos, a pipe; thirty pipes, a bottle—the last equal to one hundred and twenty-seven and a half old English gallons, or one hundred and six imperial. But the measures of the same name differ in different provinces. The arroba of Valencia contains 11·786 litres; of Malaga, 15·850; of Spain and the Canaries generally, 16·073. The cantaro of Alicante is 11·554 litres, or about three gallons, and the tonelada is one hundred cantaros; that of Arragon, 10·313; of Oviedo, 19·236. The carga of Barcelona is 123·756; the gerra of Minorca, 12·063; the mayo of Gallicia, 161·991; the quartin of Majorea, 27·131 litres, or 7·168 old gallons.

In Portugal, the almude is 25·480 litres; of Lisbon, 16·541; of Oporto, twenty-one make a pipe; at Lisbon, thirty-one, or one hundred and forty old English gallons. At Figueras the almude is 4·75 English imperial gallons; at Viana, 5·5. All these are in use in Portugal; besides which, they have potes, canadas, quartillos, basils, and toneladas; this last two hundred and thirty-one imperial gallons.

In Germany the ohm varies, at Hanover and Hamburg it is thirty-two imperial gallons; on the Rhine only twenty; at Ratisbon the bergeimer—about nineteen imperial gallons, and the same at Munich—seven and a half only; at Vienna it is ten and a half imperial gallons. The ohm at Basil, in Sweden, Dantzic, and Strasburg is a different measure from the German ohm. The ohm at the Cape of Good Hope is thirty one and two-thirds; the eimer of Leipzig, twenty and a half old English gallons, and at Dresden eighteen only; at Antwerp the aum or ohm is forty-two old English gallons.

The Russian wine-measure is the vedro of 2·705 imperial gallons; three vedros make an anker; six ankers, an oxhaff; two oxhaffs, a pipe, or 75·320 imperial gallons.

The Hungarian measures are, the antheil of 11·125 imperial gallons; the great and little eimer—the first equal to 16·140 imperial gallons, and the second to 12·515.

The other European wine measures are of little moment comparatively. In Italy they are numerous. The oke in Greece is two pounds, three ounces, five drachms, avoirdupois; and the alma of Constantinople, 1·150 imperial gallons.

Mr. CYRUS REDDING kindly tendered some valuable matter, which the Editor has incorporated in the preceding details.

ZINC.—*Zinc*, French; *Zink*, German.—It is only from the middle of the sixteenth century that zinc has been known as a metal. Its ores were known from a very early date, and were spoken of under various names; but the first account which is recorded of the term *zinc* being used in reference to the educt from the calamine or cadmia of the period, is that of ALBERTUS MAGNUS; and the first who characterized it as a distinct metal was PARACELUS, about the year 1530. For a long time afterwards, however, the knowledge of this substance was almost entirely confined to alchemists, who prized it highly on account of the property which it was thought to possess of transmuting copper into the more precious metals. It was owing to this imaginary property that the metal was long termed *counterfey* or *counterfeht* by the Germans. The present name seems to be derived from the word *zinken* or *zacken*, the German for nails or spikes, because, in preparing brass, a portion of the ore, on being sub-

mitted to a preparatory roasting, often assumed such forms. The synonym *SPILTER*, which is now so much used in commercial language, is derived from the term *spialter*, *spialter*, *et cetera*—terms which were introduced along with the first portions of this metal imported from India.

That the ores of zinc were known to the ancient Greeks and Romans, is attested by the accounts which DIOSCORIDES, STRABO, and PLINY give of one of them, or perhaps of several of them under one generic name; and likewise by the fact that in the time of these writers or at a later period, articles are known to have been produced in a kind of brass or bronze, the analyses of which clearly indicate the presence of zinc in greater or less proportion. The following analyses of different varieties of brass, dating from about the beginning of the Christian era, are given by PHILLIPS as demonstrating this fact indisputably:—

		Copper.	Tin.	Iron.	Zinc.	Lead.
Large brass of the Cassia family, B.C. 20	....	82.26	....	0.35	17.31	—
Large brass of Nero family, A.D. 60	....	81.07	1.05	—	17.81	—
Titus, " 79	....	83.04	—	0.50	15.84	—
Hadrian, " 120	....	85.37	1.14	0.74	10.85	1.73
Faustina, jun., " 165	....	79.14	4.97	0.23	6.27	9.18

Of many other bronze articles analyzed by PHILLIPS, none of them, known to have been produced anterior to the year 20 before CHRIST, were found to contain zinc as a constituent, tin being the material employed instead of that metal. The earth which was used in those early days for the purpose of forming an alloy with copper was termed *cadmia*; but it is evident that by this substance was not meant an oxide or silicious oxide of zinc, as at the present day, but any mineral, whether oxide or carbonate, that contained a large proportion of that metal, notwithstanding there being other metallic compounds associated with it. The alloy so prepared was known as *aurichalcum*, which was then recognized as a purer copper than the ordinary metal, and hence was more esteemed. The dross or oxidized portion sublimed from or remaining in the furnace after the alloy was drawn off, was likewise known by the general term *CADMIA*, but was distinguished by some particular designation, according to its color, form, or consistency. In later times this compound was distinguished at Rammelsberg as furnace calamine—*ofenbruch*—when it was discovered that it could be employed instead of native calamine in the manufacture of brass. Another substance called *TUTIA*, which seems to have been analogous to cadmia, or at least to have been a compound also rich in oxide of zinc, is spoken of in writings of the eleventh and subsequent centuries as having been employed for the manufacture of brass. ZOZIMUS, who is supposed to have written about the fifth century, states, that to make brass, cyprus copper must be melted and pounded *tutia* strewn upon it. According to ALBERTUS MAGNUS, the celebrated alchemist HERMES taught the method of making copper of a gold color by introducing pounded *tutia* into the melted metal; and ALBERTUS leaves no doubt of the nature of this *tutia*, for he states that it is not a native mineral, but an

admixture produced in the furnace when copper ore is melted—thus showing that evidently it was a sublimed oxide of zinc mixed with other ingredients, and analogous to the furnace calamine or *ofenbruch* of a later period. The discovery that this sublimate could be substituted for native calamine in the production of brass, is said to have originated with ERASMUS EBENEZER, a German, towards the middle or first quarter of the sixteenth century. The discovery was greatly esteemed, as up to that period the refuse matter from the furnaces of Rammelsberg were cast aside as useless. Doubtless the period intervening from the time of ALBERTUS MAGNUS to that of PARACELUS gradually developed facts resulting in a more comprehensive knowledge of cadmia, tutia, and the other substances containing oxide of zinc, and leading as a natural consequence to the isolation of the metal. Indeed, the former of these writers distinguished the principle in the earth which was used to convert copper into brass as *marcasita aurea*, a term which might be qualified as meaning the metal of this earth, though properly it was understood at the period as a mercurial ore, probably a sulphide of mercury. This *marcasita*, of which MAGNUS speaks as superior to the other ores of zinc, was found at Goslar; but that of which PARACELUS wrote was stated to be produced at Carinthia. By AGRICOLA, however, who wrote about the year 1550, reference is made to the Goslar product alone, which he designates as *liquor candidus* or *counterfey*; and FABRICIUS, who died in 1571, conjectures that *stibium* is what the miners call *cincum*, a compound that could be melted but not hammered.

From these different statements it will be seen that the knowledge of zinc, even for a long time after its recognition as a distinct metal, was exceedingly meagre; and in point of fact very few of the chemists of that period could obtain even samples of

it, owing, as it is alleged, to the great hopes entertained of it as an alchemical agent, and the consequent prohibition by Duke JULIUS to sell it or make it generally known. However this may be, the first certain account of its production at Goslar was given in 1617 by LÆHNEYSS, whose note in reference to it runs thus:—When the people at the melting-house are employed in melting, there is formed under the furnace, in the crevices of the walls, under the stones where it is not well plastered, a metal which is called zinc or *counterfeht*, and when the walls are scraped the metal falls down into a trough to receive it. This metal has a great resemblance to tin, but it is harder and less malleable, and rings like a small bell. It is not much valued, and the servants and workmen collect it only when they are promised drink-money. They, however, scrape off more of it at one time than at another; for sometimes they collect two pounds, but at others not above two ounces. This metal by itself is of no use, as, like bismuth, it is not malleable; but when mixed with tin, it renders the latter harder and more beautiful, like English tin. This zinc or bismuth is in great request among the alchemists.

BECKMANN KENKELL is accounted to have been the first who procured it directly from calamine in 1741. After him LAWSON is stated to have succeeded in extracting it from the ore, though no account of his researches exist. VON SWAB, a Swede, obtained it by distillation from calamine in 1742; and almost contemporary with him MARGGRAF likewise discovered a process for the same purpose in 1746. It is stated by WATSON in his chemical essays, that in 1743 a manufactory for the production of this metal was established at Bristol, by CHAMPION, and was carried on by his successor, EMERSON, who established another in the neighborhood. It appears, however, that the wants of Europeans, as regards this metal, were supplied from China and India, through the Dutch, and probably the Portuguese, the imported articles bearing the title *tutenague*, or Indian tin. RAYNAL records that the Dutch East India Company purchased annually at Paliubang a million and a half pounds of this metal; and the Danish Company at Copenhagen, in 1781, as much as one hundred and fifty-three thousand nine hundred and fifty-three pounds. It appears, however, that between the above date and 1820 the production of zinc must have greatly increased, as it is recorded that at the latter date spelter or zinc was imported into England from Silesia, to be again exported to India to supply the place of the *tutenague*, formerly imported from China. The Silesian zinc was analogous in composition to the Chinese product, as will be seen by the subjoined figures:—

	Zinc.	Lead.	Iron.	Sulphur.	Sand.
Silesian zinc, . . .	98.32	1.40	—	0.18	0.10
Chinese tutenague,	97.63	0.33	1.90	0.14	—

The quantity exported from England to India almost balanced the total amount of her imports, until about 1830, when the quantity retained for home consumption began to be increased annually, so that in 1851 the amount thus utilized reached eleven thousand two hundred and sixty-two tons, while the quantity imported in the same year amounted to eighteen

thousand six hundred and twenty-six tons, whereas the exports to India remained nearly the same. At present Silesia is the great seat of the manufacture of zinc, containing the largest works of the kind in the world, and producing as much as fifty-three per cent. of the total yield of all countries. Belgium, including more especially the works of the *Vieille Montagne* Company of Liege, ranks next, and produces about thirty-three per cent.; Poland and Cracow furnishes ten and a quarter per cent., and England the remainder.

The application of zinc within the last twelve years has been very much extended, not only for use in brass foundries, but in several other departments, such as in galvanizing iron for light roofing and for fencing, and in fact for all the lighter kinds of iron which have to be exposed to the air; for the base of electro-plated articles, for paint, and various other applications.

OCCURRENCE OF ZINC.—This metal is never found in the native or virgin state, but always combined with oxygen, sulphur, and salt radicals. Ores of zinc are met with in almost every country, though not to such an extent in many of them as to render them particularly important in a metallurgical point of view. The most remarkable deposits of these ores hitherto discovered are those in New Jersey in the United States, where almost every variety of the natural combinations of zinc are met with. They exist in considerable quantities in Siberia and on the continent of Europe, more especially in Silesia, Hungary, Carinthia, Saxony, Belgium, Sweden, and France; also in England and Scotland, and some parts of Ireland. The most famous localities where the deposits occur will be mentioned presently in specifying the particular ores of zinc.

ORES OF ZINC.—The most important ores of zinc, not only as containing more of the metallic element, but also as affording greater facilities for its extraction, are the oxide, carbonate, sulphide, and silicates.

OXIDE OF ZINC—SPARTALITE—red oxide of zinc, zinc oxide ferriifère; zinc erze; zinkit.—Generally this ore is met with in the amorphous state, but it is occasionally found crystallized in forms of the rhombohedral system, the crystals appearing colorless or yellowish-red, according to the purity of the compound; their lustre is adamantine, appearing translucent on the edges, having a cleavage parallel to the base and one of the sides, a conchoidal fracture, and a specific gravity equal to 5.43 to 5.52. Crystallized oxide of zinc is infusible before the blowpipe, though it phosphoresces strongly; with borax and phosphorous salt the presence of manganese is indicated in it, while that of zinc is shown by the green color produced in the assay, when it is moistened with nitrate of cobalt solution, and subsequently heated to strong redness. The powdered crystals, as well as the amorphous substance, dissolves readily without effervescence in nitric acid. Its composition is—

	Whitney.		Hayes.	Berthler.
Oxide of zinc,	94.45	96.19	93.48	88.0
Oxide of manganese,	trace	3.70	5.50	12.0
Franklinite,	4.49	—	—	
Oxide of iron,	—	0.10	0.80	
Loss by ignition, &c.	1.06	0.01	0.22	—
	100.00	100.00	100.00	100.0

CARBONATE OF ZINC—*calamine*; *zinc carbonaté*, *Galnei-Smithsonite*; *zinc spar*.—This is by far the most important ore of zinc, and that from which the metal is chiefly extracted; it is more diffused than any other, and offers, like the oxide, peculiar facilities for smelting. Calamine is usually found in a crystallized state, in concretioned and compact masses, and in pseudomorphic forms. The crystallized variety when pure has a vitreous, inclining to a pearly lustre; is colorless, white, grey, green, or brown, according to its freedom from extraneous matters. Its crystalline form is that of the rhombohedron, with a cleavage parallel to its faces.

Its fracture is uneven or imperfectly conchoidal; its streak white, and its specific gravity 4.34 to 4.45. The ore is infusible before the blowpipe, but affords a white sublimate of oxide of zinc when it is heated on the charcoal, and which is yellowish while hot, and becomes white on cooling. By moistening the assay with a solution of nitrate of cobalt, and then heating, the green color peculiar to zinc under such treatment makes its appearance. It is readily soluble in acids with the evolution of carbonic acid, and in an excess of caustic potassa. The following analyses of a few samples of the mineral indicate its composition:—

	Smithson.		Karsten.			Berthier.
	1	2	3	4	5	6
Oxide of zinc,	64.8	65.2	57.76	61.53	64.36	60.7
Carbonic acid,	35.2	34.8	35.62	35.47	35.14	35.0
Protoxide of manganese, ..	—	—	6.62	—	—	—
Oxide of lead,	—	—	—	—	0.50	—
Oxide of iron,	—	—	—	—	—	4.3
	100.0	100.0	100.00	100.00	100.00	100.0

Samples 1 and 2 in the preceding table represent calamine from Somersetshire and Derbyshire; 3 is from Nertschinsk, 4 from Altenberg, 5 from Brilon, and 6 from Taina in Siberia.

Annexed are a few analyses of other samples of

calamine more manganiferous than the foregoing. Number 1 specimen represents the calamine in yellowish white crystals from Altenberg; No. 2, light green crystals from Nirm; No. 3, dark green crystals; and No. 4, calamine from Nertschinsk:—

	Monheim.			Kobell
	1	2	3	4
Carbonate of oxide of zinc,	84.92	85.78	74.42	96.00
Carbonate of protoxide of iron,	1.58	2.24	3.20	2.03
Carbonate of protoxide of manganese,	6.80	7.62	14.98	—
Carbonate of oxide of lead,	—	—	—	1.12
Carbonate of lime,	1.58	0.98	1.68	—
Carbonate of magnesia,	2.84	4.44	3.88	—
Silicate of oxide of zinc,	1.85	—	—	—
Silica,	—	0.09	0.20	—
Volatile matter,	—	—	0.56	—
Loss,	0.43	—	1.08	0.85
	100.00	101.15	100.00	100.00

Very frequently the silicated oxide of zinc and the carbonate are confounded under the title calamine. Two principal classes of calamine are recognized, namely, ordinary white calamine, which may be a carbonate or a silicate of the oxide, containing but a very small proportion of ferruginous matters, and the *red*, which differs from the foregoing, but only by its containing more hydrated sesquioxide of iron or its salts.

The following are analyses of red calamine by JOHN:—

	From Rudipkar.	From Beuthen.
Oxide of zinc,	39.00	35.00
Carbonic acid and water, ...	15.00	{ 24.37
		{ 10.63
Oxides of iron, manganese, } lime, and silica,	46.00	3.000
	100.00	100.00

Calamine, as well as *blende*, is found in two geological formations—the one is the carboniferous or mountain limestone, in which it occurs in veins accompanying galena; and the other the magnesian limestone formation of English geologists, the Alpine limestone of the French, and the *Zechstein* of the Germans, in which it is disseminated in small veins forming a network in the mass, not more than a few inches in thickness, except where several intersect, when it sometimes increases to

as many feet. Explorations for lead and zinc are carried on in England, wherever the mountain or metalliferous limestone exists; but the principal seats of operation are in the neighborhood of Alston Moor in Cumberland, of Castleton and Matlock in Derbyshire, and in Flintshire in Wales. In the magnesian limestone the explorations for calamine are prosecuted chiefly on the flanks of the Mendip hills, near Bristol; and the mineral is excavated by means of numerous small shafts and levels. Calamine usually occurs in beds and veins, associated with Smithsonite galena, blende, and other minerals, in the crystalline slates, transition rocks, the coal formations, the muschel kalk, and oolite formations. It is found at Altenberg and Nirm, near Aix-la-Chapelle; at Iserlohn and Brilon in Westphalia; near Tarnowitz in Silesia; at Raibel and Bleiberg in Carinthia; in the Banat; at Miedziana Gora in Poland; Dognazka, Rezbanya, and Saska, in Hungary; at Kuesiana in Servia; Tschairski in the Altai; Nertschinsk and Nischn Tagilsk in Siberia; Chessy in France; in Belgium; in several places in the United States, especially in Jefferson County, and many other localities.

SILICATE OF OXIDE OF ZINC—*Smithsonite*, Phillips; *zinc oxidé silicifère*, Haüy; *zink-glas*, Hausmann; *galmei*, Haidinger.—Two varieties of this mineral exist;

the one anhydrous and the other hydrated. Anhydrous oxide of zinc is found crystallized in regular hexahedral prisms of a green or grey color; translucent, sometimes transparent, with a vitreous lustre on the surfaces of the fracture, which is somewhat conchoidal and uneven. Its streak is white. Before the blowpipe it is infusible, and is only reduced when mixed with charcoal, and submitted to a very high temperature; heated with soda on charcoal, it affords a sublimate of oxide of zinc; with a solution of nitrate of cobalt it affords the characteristic green color of zinc; it is decomposed by mineral acids, yielding a jelly of silicic acid. It is composed of—

Oxide of zinc,.....	71.32
Oxide of lead,.....	2.66
Oxide of iron,.....	0.67
Silicic acid,.....	25.35
	100.00

HYDRATED SILICATE OF ZINC—*Electric calamine*.

—Silicates of zinc, especially this variety, were long confounded with calamine or carbonate of zinc, notwithstanding the great difference which exists between the two minerals. Electric calamine occurs in stalactic, mammillated, botroidal, and massive forms, as well as in crystals of the right rhombic system. Its usual color is white, but in this respect it varies to shades of yellow, brown, green; its lustre is vitreous, and its streak white; it is phosphorescent when rubbed, and becomes electric by heat; its streak is white; it has an uneven fracture, and a specific gravity of 3.3 to 3.6. When heated on the matrass it yields water and turns white. It swells on charcoal before the blowpipe, and shines with a green light, but does not fuse, excepting a little on the edges; in other respects it comports itself like the anhydrous compound. The pure silicate is composed of—

Oxide of zinc,.....	67.07
Silicic acid,.....	25.48
Water,.....	7.45
	100.00

corresponding to the formula $\text{ZnO}, 2 \text{SiO}_2 \text{HO}$. In most cases, however, this mineral is associated with various extraneous matters, as shown in the annexed analyses—

	Berzelius. 1	Berthier. 2 3	Smithson. 4	Thomson. 5
Oxide of zinc,.....	66.84	66.0 64.5	68.3	66.8
Silica,.....	24.89	25.0 25.5	25.0	23.2
Oxides of lead and tin,.....	0.28	— —	—	—
Water,.....	74.45	9.0 10.0	4.4	10.8
Carbonic acid,....	0.54	— —	—	—
Loss,.....	—	— —	3.3	—
	100.00	100.0 100.0	101.0	100.8

Numbers 1 and 2 in the foregoing table were from Limburg, 3 from Breigau, 4 from Rezbanya, and 5 from Leadhills.

This mineral is generally associated with calamine in veins containing iron and lead ores and blende; it is found in most of the localities already mentioned as containing calamine. Considerable quantities of it are mined at Bleyberg and Raibel in Carinthia; in Brisgau, Hungary; and at Tarnowitz in Silesia; it is also found in Poland, Galicia, Baden, in the Tyrol, and in Banat; at Alcares in Spain; at Altenberg, near Aix-la-Chapelle; at Morcsnet, near Liege; near Goslar in the Hartz; at Matlock, Derbyshire; in the Mendip Hills and Flintshire in England; at the Wanlock-head; and the Leadhills in Scotland, and several other localities.

SULPHIDE OF ZINC—*Blende; zinc sulfuré; zink-blende*.—Blende occurs in a variety of conditions—massive and crystallized in octa- and dodecahedrons and other allied forms, derived from the cubic system, its color varying between black, brown, red, yellow, and green. The crystallized variety is translucent, transparent, and opaque; it has an adamantine lustre, a conchoidal fracture, and a cleavage parallel to several of its faces; it gives a white, shading off to a reddish-brown, streak, according to its purity; it is brittle, and has a specific gravity of 4.0 to 4.1. By friction some varieties are rendered electric. Heated alone it decrepitates violently; it is infusible, excepting slightly on the edges in the blowpipe flame; but it gives, under a strong oxidizing flame, a sublimated arc of oxide of zinc round the assay; with carbonate of soda on charcoal it is reduced. When treated with nitric acid the base is dissolved, and the sulphur left in proportion to the strength of the acid employed. When pure, sulphide of zinc consists of equivalent proportions of its constituents, corresponding to the formula ZnS , and is composed centesimally of—

Zinc,.....	67.03
Sulphur,.....	32.97
	100.00

Generally, it contains several impurities, such as sulphides of iron, of lead, of cadmium, and of antimony; the first of these is more frequently met with in the dark, and the second in the reddish striated kind. The following are analyses of a few samples of blende from different localities; namely, those marked 1, 2, and 3, from Przibram; 4, a transparent variety from New Jersey; 5, from Bagnères de Luchon; 6, from Chéronnes, in the department of Charente; 7, from Raibel in Carinthia; 8, from Eaton; 9, from Shelburne in New Hampshire; 10, from England; and 11, from Christiania:—

	Lowe.		Arfredson.	Henry.	Berthier.	Lecanu.	Kersten.	Jackson.		Berthier.	Scheerer.
	1	2	3	4	5	6	7	8	9	10	11
Zinc,.....	61.40	62.62	66.34	66.46	63.0	55.0	64.22	63.62	52.0	61.5	53.17
Iron,.....	1.29	2.20	—	—	3.4	8.6	1.32	3.10	10.0	4.0	11.79
Cadmium,.....	1.50	1.78	—	trace	—	—	trace	0.60	3.2	—	—
Antimony, lead, and oxygen,....	—	—	—	—	—	—	0.72	—	1.3	—	0.74
Manganese,.....	—	—	—	—	—	—	—	—	—	—	—
Sulphur,.....	33.15	32.72	33.66	32.22	33.6	36.2	32.10	33.22	32.6	33.0	35.73
Water,.....	—	—	—	—	—	—	0.80	(earthy matters 1.5)		—	—
Loss,.....	2.66	0.68	—	1.32	—	0.2	0.84	—	0.9	—	—
	100.00	100.00	100.00	100.00	100.0	100.0	100.00	100.54	100.0	100.0	101.43

7 G

Blende is found, as before stated, in the metalliferous mountain and magnesian limestone, especially in England, in veins and beds associated with lead, iron, and copper ores. In Cornwall its presence is observed in the older transition rocks, and chiefly accompanying copper pyrites. The variety so found, from the large quantity of sulphide of iron, is mostly of a black color—hence the miners term this mineral *black jack*. The ore is found in more or less abundance in Hungary, Transylvania, Bohemia, Carinthia, and the Hartz; large quantities of it are obtained in Cumberland, Derbyshire, and Cornwall, in England; Flintshire, in Wales; in Perthshire, the Leadhills, and the coal fields round Edinburgh and Lanarkshire, in Scotland.

SULPHATE OF ZINC.—*Goslarite, zinkvitriol, white vitriol, aluminate of zinc, galnate spinelle, zincifère*, and a few other minerals of zinc exist; but their importance in relation to their abundance, or for their application in the metallurgy of zinc, is not so great as to require a description here.

PREPARATION OF ZINC.—To obtain perfectly pure zinc is a task of some difficulty, so much so that the commercial article is never met with in a pure state, but rather with variable quantities of arsenic, cadmium, tin, lead, manganese, iron, cobalt, and nickel. In order to obtain perfectly pure metal, the purest commercial zinc should be dissolved in dilute sulphuric acid, filtered from any residue, and the foreign metals thrown down by immersing plates of zinc in the liquid till no further deposit takes place. After separating the precipitated metals, which may be tin, lead, copper, cadmium, antimony, and a trace of arsenic, the solution is treated with carbonate of soda, and the carbonate of zinc, which falls after filtration and thorough washing, is dried, heated to redness to expel carbonic acid, mixed with charcoal or lampblack, and introduced into a crucible as represented in Fig. 623, placed in a furnace,

Fig. 623.



and the metal reduced and recovered by the method known as distillation *per descensum*. In this figure, the crucible wherein the mixture of carbonate and charcoal is placed, is shown by A; it rests upon a disc of clay, B, which, together with the bottom of the crucible, is perforated for the purpose of passing a clay tube through both, one end of which opens at the top of the crucible near the cover, and the other dips into a cup of water, C, placed beneath the grate and ash-pit. The crucible being fixed, with its charge and its cover closely luted with clay, is placed in the furnace and heated to whiteness, when the reduced particles of the metal pass off in vapor, which finds an outlet in the lower opening of the tube, and condenses in the cup of water in grains. The zinc obtained in this way will be very pure, but to obtain it in absolute purity, it is necessary to have recourse to electrolysis from a solution of zinc which has undergone the above-

mentioned purifying operation, and from which the iron, manganese, and other bodies which may be deposited on the electrode, are separated by treatment with an excess of caustic potassa, subsequent precipitation of the zinc as carbonate, washing, and re-solution. The distillation of zinc being always conducted at a white heat, a repetition of the distillation, however often repeated, is not sufficient to separate many impurities of a metallic nature, which greatly injure its properties, and prevent its applications in many operations of a chemical and manufacturing nature. The substances with which it is most liable to be contaminated when prepared in this way, are lead, tin, antimony, cadmium, and arsenic, as these metals evaporate with the zinc and alloy themselves with it. A simple process adopted to free zinc from several of the preceding metals consists in incorporating some sulphur alone or mixed with grease in the melted metal, and stirring the whole rapidly with a wooden slip. The foreign metals are by this operation converted into sulphides, but traces of them are still retained in the melted zinc. Another method is to granulate the zinc by melting it in a crucible, and pouring it while fluid into a tub of water, then mixing the powder with a quarter of its weight of nitre, and introducing the mixture into a crucible, taking care that a portion of the salt rests beneath and upon the metal. The crucible is then heated in a furnace till vivid combustion ensues, after which it is taken from the fire, the slag removed from the surface, and the melted metal poured into water. Arsenic and iron are thus removed.

PROPERTIES OF ZINC.—When pure, this metal has a bluish white color, somewhat similar to lead or aluminium, and a strong metallic lustre. It crystallizes in long regular hexagonal prisms, according to NAGGERATH, but others give the crystalline form as cubic prisms. NICKLES asserts that zinc distilled in an atmosphere of hydrogen forms well-defined pentagonal dodecahedrons on cooling. When freshly fractured, its crystalline texture is lamellar, the plates sometimes appearing of considerable size. At ordinary temperatures it is brittle, of a moderate hardness, and difficult to file, but when heated between 212° and 300° it acquires a considerable degree of malleability, so that it can be drawn into wire or rolled into thin bands and sheets. Mr. FORD of Coalbrook Dale, who, according to GRAY, was the first person in England who employed the metal in casting fire-engine cylinders, states that, by the mere warmth of the hand, the strips of metal which were as brittle as glass at the ordinary temperature, could be wound round the finger like slips of paper. If the heat be raised to 400° or 410° its ductility is destroyed, and it becomes so brittle as to be reduced to powder in a mortar by ordinary grinding processes. Zinc emits a peculiar odor when rubbed. Its density, according to the mean of several experiments of BRISSON, KARSTEN, PLAYFAIR, and JOULE, is 6.89; the melted metal after cooling gave JOULE only 6.54. It fuses at 705° according to GUYTON MORVEAU, but DANIELL gives the fusing point 774°; at white heat it boils, emitting vapors which burn in the air or in oxygen gas with a very brilliant white light, producing oxide of zinc, which

condenses in filamentous flocks on a cold surface held over the flame, or on the walls of the crucible in which the combustion is effected; this is the *philosophical wool*, the *flowers of zinc*, or *pompholyx* of the old chemists. At a red heat zinc decomposes water, setting free the hydrogen of the vapor; the same effect is produced at ordinary temperatures under the influence of weak acids, and with considerably greater energy than by heat alone. In the latter behavior a remarkable difference is manifested when pure and commercial zinc are submitted to the action of the same acid, the former dissolving so slowly that it requires the action to be continued for a period of eight days to produce the same effect as that which is effected upon the latter in a space of one hour. This behavior was made the subject of a careful investigation by DE LA RIVE, who found that the action of the acid is increased by the presence of certain proportions of many metals. By alloying nine parts of pure zinc with one part of the several metals mentioned below, and employing dilute sulphuric acid, he found that the effect of the acid, measured by the volume of hydrogen disengaged in equal times, stood in the relation of the annexed numbers:—

	Gas disengaged.
Commercial zinc and alloys of zinc and iron,...	100
Alloy of zinc and copper,.....	43
Alloy of zinc and lead,.....	15
Alloy of zinc and tin,	12
Distilled zinc,	5

One twentieth of the quantity of iron alloyed with zinc is sufficient to produce an effect equal to that of commercial zinc, and even a spiral of platinum round a bar of zinc was found to increase the action of the acid considerably. On the other hand, he observed that the acid which effected the most rapid solution of the metal, was a mixture of thirty-three parts of sulphuric acid and one hundred of water. The consideration that the zinc, on being alloyed with any metal, constitutes a kind of battery within itself, and the knowledge that the above acid is the one which possesses the greatest power of conducting electricity, led M. DE LA RIVE to the conclusion that the greater or less energy with which a plate or bar of zinc decomposes water, is dependent upon the galvanic effect of the metals associated with the zinc and of the acid body employed.

Zinc abstracts oxygen from a great number of acids containing this element. Boiling solutions of potassa and soda likewise oxidize it with disengagement of hydrogen, the oxide of zinc formed dissolving in the alkali, and forming probably the radical of an alkaline salt. Exposure to dry air, however long continued, is insufficient to tarnish bright metallic zinc; but when moisture is present it readily undergoes oxidation, a whitish coating forming upon it; this, however, retards to a great degree its further corrosion by atmospheric influences, so that it resists exposure very well; and hence, its very extended use in roofing and other applications where iron would soon become oxidized and worn away. Zinc forms an extended class of salts with acids, many of which are of some importance in many departments of art and manufactures as well as in medicine, and the metal itself has of late years been applied to a great many important uses. Zinc has the

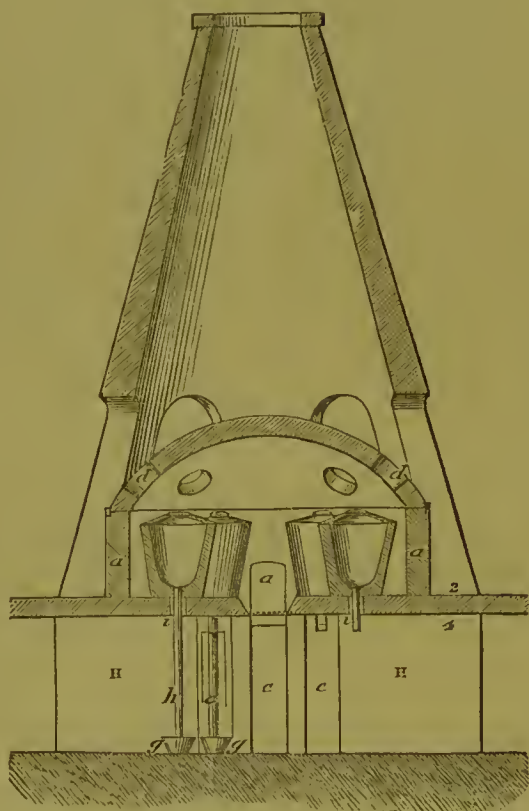
atomic or combining number 32; and its symbol, or chemical formula, is Zn.

METALLURGY OF ZINC.—The principal places for the production and manufacture of zinc are, in England, Swansea, Carlisle, Bristol, Birmingham, and the neighborhood of Sheffield; Flintshire in Wales; Upper Silesia in Germany; and Vieille Montagne in Belgium. The latter establishment has considerably increased during the last twelve years, but it has not attained the magnitude of the Silesian works, which are the largest of the kind in the world.

ENGLISH PROCESS.—The ores which are principally employed at Bristol and Birmingham, are those from the Mendip Hills and from Flintshire, while the Sheffield furnaces derive their stock from Alston Moor in Cumberland, and from Derbyshire. A large quantity of blende is likewise obtained from Cornwall, which is submitted to a preparatory roasting. The ore is sorted, and any blende which may be mixed with it is separated from the calamine; the latter is sometimes ground under head rollers, and roasted in a reverberatory furnace, to expel all its moisture and carbonic acid. This preparatory roasting is not universally practised, however, as some smelters merely break it up into fragments about the size of a pigeon's egg, and in this state mix it with its bulk of coal or slack, and submit it to the reduction process. Blende is always roasted before reducing it to metal, for which purpose it is sorted and broken up into small pieces of about half a cubic inch, and introduced into a reverberatory furnace, where it is roasted during ten to twelve hours without intermission. The furnace is ten feet long, eight feet wide, a half foot between the bed and the roof in the middle, and one foot and a half at the bridge. A continual rabbling is given to the ore, which is spread on the bed to the depth of four or five inches. During the period of the roasting, the ore suffers a loss of twenty per cent. from the sulphur expelled. Four tons of coal are said to be consumed during each operation. The charge for reduction is then compounded of one part of calcined blende, one part of roasted calamine, and two parts of charcoal. In the English system, the furnaces shown in the annexed figures are employed; their peculiar feature is their being adapted to the practice of the system of distillation *per descensum*. They consist, as shown in Fig. 624, of an inner cupola, A A, enclosing a double row of crucibles, G G, the whole enclosed by a hovel or conical brickwork chimney, D, similar to that of a glass furnace or pottery kiln. A number of openings, B B, are constructed in the cupola corresponding to the number of pots in the furnace, and which serves to charge and secure the pots in their places when necessary. For the convenience of the workmen the outer cone has doors, C C, before each pot. A fire, F, runs across the centre of the hearth and heats the row of four pots on either side, the smoke and gases passing off by the apertures, B B, and outwards at the mouth of the cone, D. The ash from the grate falls into the pit, E, at either side of which, and beneath the pots, is a gallery, H, where a number of dishes or other vessels are placed for collecting the zinc, conducted to them by iron pipes, having one end inserted into the aperture in the bottom of the pot, while the other

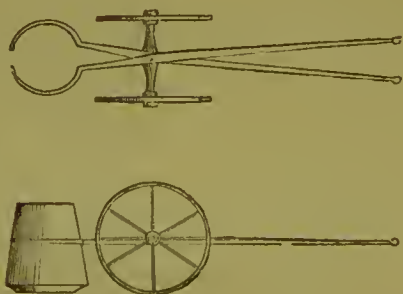
dips into the dish already mentioned. To charge the furnace, the crucibles, which are previously heated to redness in a reverberatory furnace, are carried by a pair of large iron pincers, slung in chains, and supported on a kind of over-head railway—Figs. 624, 625—much in the same way as glass-pots are inserted

Fig. 624.



and withdrawn from the furnace. They are then introduced by means of an aperture in the side of the dome, and placed in their position beneath the apertures in the top, so as to rest on each side of the wall

Fig. 625.



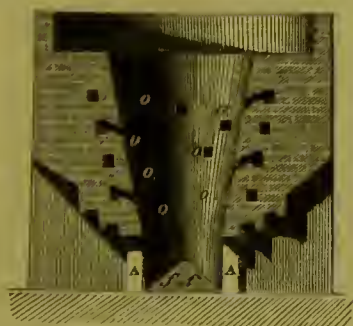
of the furrow opening into the chamber, H. The charge for each pot or crucible is composed of equal bulks of ore and slack when calamine either crude or roasted is used, or if a mixture of calcined blende and calamine be employed; these, in the proportions already stated, are introduced through the apertures in the dome, the outlet in the bottom of the pot being secured by a plug of wood. The fire is then urged till the contents of the pots are brought to a full red heat, approaching to whiteness, and when the vapors arising from the ore are observed to burn

with a white light, the covers are placed upon the several pots and well luted, the pipes are likewise inserted in the bottom, and the distillation is allowed to proceed, the temperature being always maintained at a high white heat. To prevent the materials in the pot from falling through, the end of the pipe is plugged with wood, but as it becomes charred, it offers sufficient space for the metal, in its passage downward, to percolate through it without allowing any grosser matters to descend. Any metal condensed in the pipes is removed by introducing, from time to time, a small iron rod or wire, which clears it away; if this operation be neglected, the outlets are apt to get clogged up, and the tension of the enclosed gases will endanger the explosion of the covers. Usually the period occupied in a single distillation is about sixty-six hours, or five distillations in fourteen days, in which from eight to ten tons of ore are worked off, with a consumption of twenty to twenty-five tons of coal. The metal obtained amounts to thirty-five or forty per cent. of the calcined ore employed. When no more metal is condensed, the refuse matter in the pots is discharged by removing the pipe in the bottom and the cover, and then raking it out through the bottom aperture; after this operation the latter is plugged, to prepare the retort for receiving another charge. Each pot serves to distil about forty charges before it gets broken; when this happens, the fragments are withdrawn through an opening made in the surrounding brickwork, and the place of the broken pot is supplied by another annealed at a red heat in a reverberatory, as mentioned above. The collected product of the distillation, which is chiefly in drops and fine metallic powder mixed with some oxide of zinc, is melted in a large iron pot set in brickwork, and heated by a fire beneath it, when the lighter oxide and other impurities form a scum on the surface of the bath of melted metal; the former is skimmed off, and the latter cast into bars or cakes, in which state it is sent to market.

PROCESS PRACTISED AT VIEILLE MONTAGNE.—The mineral wrought at this establishment is a mixture of calamine and oxide of zinc, which is of a very compact and crystalline nature, intermixed with a gangue of clay in amorphous masses. As a preparatory operation, the mineral substance, as taken from the mine, is exposed to the air for the purpose of allowing the gangue to disintegrate, with the view of rendering its separation more easy and complete in the preparatory process to which it is submitted. There are two varieties of the carbonate treated, one of a reddish color, containing a considerable amount of iron; the other white and more compact. The ore is placed in heaps, and turned over from time to time to permit the air to pass through it more freely. After a period, varying from three to twelve months, the heap is picked, and the fragments of pure ore of the size of pigeons' eggs are selected from the rest. The refuse matter is then screened, and the coarser portions again picked out by hand; finally, the reduced fragments are washed upon the inclined plane, and the chief part of the clay is thus removed. There is a considerable difference between the periods required to disintegrate the two varieties of the mineral: by a

three months' exposure the red kind is sufficiently decomposed to part with the most of its impurities, whereas the white variety takes from nine to twelve months to effect the same change; in the former the loss averages fifteen per cent., whilst in the latter it often amounts to fifty. The selected ore is then calcined, sometimes in a reverberatory, but more frequently in a conical kiln, somewhat similar in form to that in which lime is burned, and which has the advantage of being continuous in its operation. Fig. 626 represents this kiln: it is heated by two lateral fires inclosed within an arch, the products of combus-

Fig. 626.



tion from which are draughted into the interior from a channel or flue by twenty different apertures, *o, o, o*, at various points of elevation. The bottom of the kiln inclines towards the drawing doors, *A, A*, owing to the two cast-iron plates of which it is composed, *f, f*, being laid together at an angle of 45° , and hence the descending body of calcined ore falls in almost equal portions towards each of the rectangular outlets already mentioned. Coal is preferred for heating in this case, owing to the high temperature necessary to calcine the mass of ore which is introduced at regular intervals at the top. After drawing out the roasted ore it is ground under headstones, and sifted, so that its fineness is insured; it is then mixed with its proper quantity of combustible matter, which may be charcoal or fine coal, and introduced into the retorts for smelting. These retorts consist of cylinders of refractory clay, closed at the end which is inserted into the furnace, and open at that one which protrudes; to this end is adapted another cylinder of sheet-iron of a conical form, for the purpose of condensing the metallie vapor, and this in turn has a third pipe of the same form, but much smaller, appended to it. These several parts are seen in Fig. 627, *A* being the retort, *B* the condenser, and *C* the outer cone;

Fig. 627.



the first is three feet eight inches in length, and six inches in diameter, the second is sixteen inches in length, and the third about the same, only that both taper, so that the aperture of the apex of *C* is not greater than three-fourths to one inch in diameter. These are placed in a peculiar kind of furnace represented in elevated section in Figs. 623 and 629, the

latter in the line *A B* of the former. The stack consists of four distinct furnaces, each in the form of a semi-cylindrical chamber, eight feet eight inches from the highest point of the arched roof to the floor, the back of the chamber being constructed so as to recede slightly from the bottom or floor upwards, as shown by *b d*, in Fig. 629, and the front, *a c*, being left open for the convenience of introducing the retorts. The fire which heats the chamber and its complement of retorts is shown at *F*, and is placed beneath the level of the floor of the smelting house, the combustible gases and other products passing upwards through four apertures in the grate, shown at *e, e, e*, and thence by a double flue, *G, G*, finding an exit overhead into the chimney, *C*. The latter forms one massive construction, embracing the four outlets, each closed by a damper. In each of the chamber furnaces forty-two retorts, *G, G*, are heated; these being placed in rows one above the other, as shown in the drawing, the posterior end resting upon a ledge made for the purpose in the masonry or brickwork. In the front the distillatory cylinders are supported by plates of cast-iron, so fixed at each side of the face of the furnace as to allow the cylinders to slope downwards from the back to the front. Before placing the retorts in this furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a bright red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which should be previously heated to redness in a reverberatory, are fixed in their places one by one, the interstices between each retort at the front being closed up with fire-clay. At first, a small quantity of the mixture of ore and coal is submitted to reduction in the cylinders, the condensing cone and adapter attached and luted, and any metal given out collected in the manner presently to be indicated. These preliminary charges are successively increased for a period of three or four days, or until the furnace is found to be in a proper working condition. At this period the charge attains its mean, and consists of one thousand one hundred pounds of the roasted, ground, and sifted calamine, intimately mixed with five hundred and fifty pounds of bituminous coal in fine powder, for the forty-two retorts. This is introduced into the clay cylinders by means of a long half-cylindrical shovel attached to a long iron handle, commencing with the lower retorts, and proceeding to the higher ones in succession. When all are filled, the flue, which is usually stopped by having the damper down, is opened, and an increased firing resorted to.

As the contents of the retorts attain a strong red heat approaching to whiteness, they evolve a considerable amount of carbonic oxide, which burns at the mouth of the cylinders with a bluish flame; after a while the appearance of

the flame becomes more brilliant, and of a greenish white, showing that portions of the zinc vapor have been volatilized. As soon as this symptom is observed, the iron condensing tubes are attached to the open end of the retorts, the joining is well luted with refractory clay, and finally the adapters being fixed upon the condensers and luted likewise, the distillation and recovery

of the zinc are proceeded with. Every attention is now given to equalize the heat in the interior of the furnace, in order that the upper retorts may be worked off equally well with the lower ones; but this result can

seldom be exactly attained, and to compensate for this defect the more easily reducible ores are charged into the upper retorts, and the more refractory into the lower ones, where the heat is greatest. At intervals

Fig. 628.

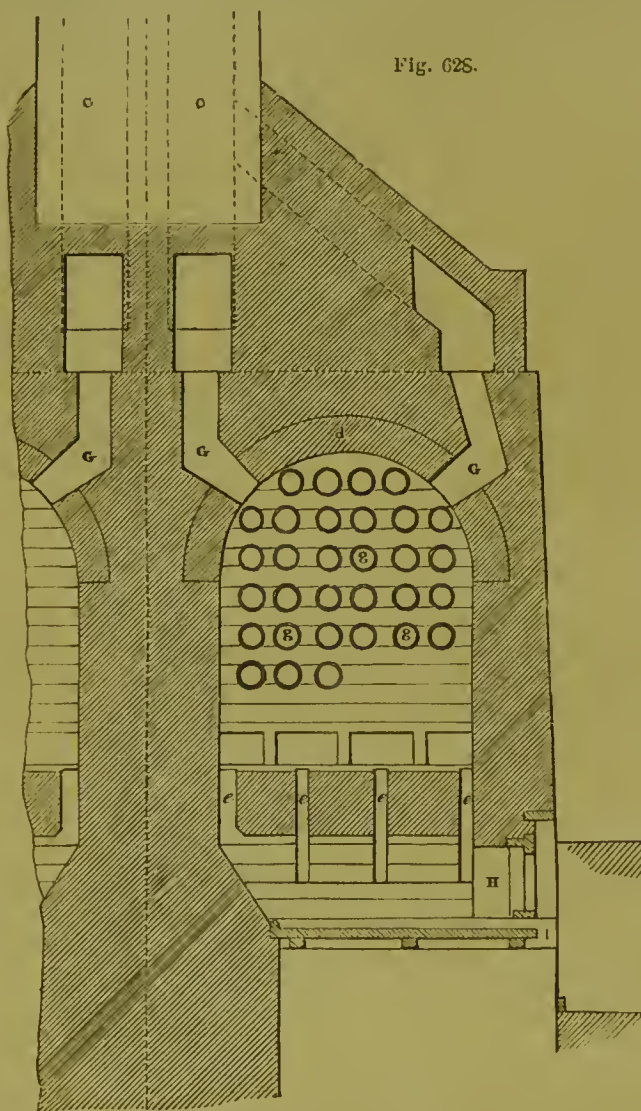
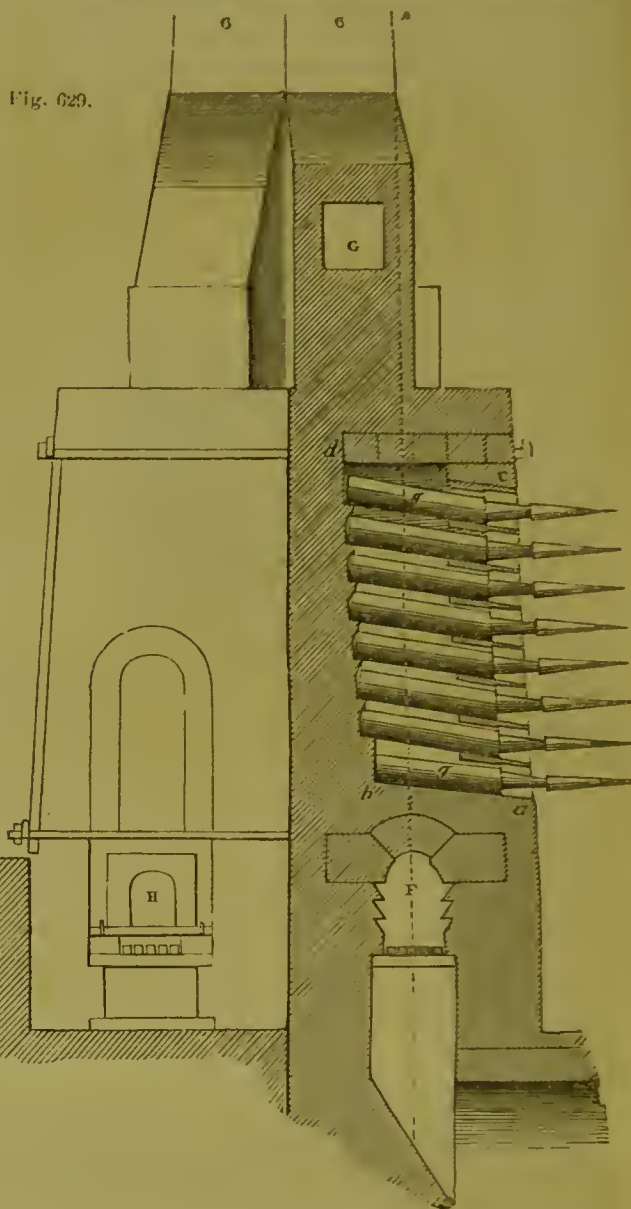


Fig. 629.



of two hours after the distillation commences, the outer adapter is removed by means of tongs, and the oxide of zinc, or *cadmia*, collected in it is removed, to be again submitted to the retorts in a succeeding charge. An assistant then holds a large iron ladle, called a *poêlon*, under the mouth of the condenser pipe, and the smelter rakes out the fluid zinc at the bottom of it, as well as the drops of metal attached to the sides and other parts. After carefully separating the oxide of zinc which covers the metal thus abstracted, the latter is cast into ingots, weighing from seventy-five to eighty-five pounds. The adapters are then replaced and secured as before, and after two hours the zinc produced is again removed in the manner stated.

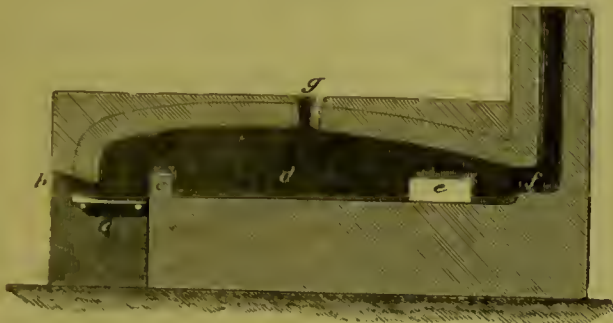
A charge of ore commenced at six in the morning, and worked in this way, is found to be exhausted of its reducible metal at five in the afternoon, so that two charges are worked in the twenty-four hours. When one operation is finished, the adapters, con-

densers, and retorts are thoroughly cleansed and scraped out before the next charge is introduced; and the oxide resulting from every operation and collected from the adapters and skimmings, is worked up as part of the ore of the preceding charge. The argillaceous residue cleared out of the retorts after the distillation has ended, is found to contain as much as ten per cent. of zinc; but being in the form of silicate of oxide, it resists the action of the charcoal and remains intact. About thirty per cent. of the calamine submitted to reduction is obtained in the form of metal. The distilling campaign lasts two months, during which time the fires are maintained at their greatest activity consistent with the work to be accomplished. At the end of this period, the necessity for repairs and replacing old retorts compels a cessation of the smelting for the time required to effect the necessary renovation.

Process for the Smelting of Zinc Ores in Upper Silesia.—The ores of zinc worked in this district

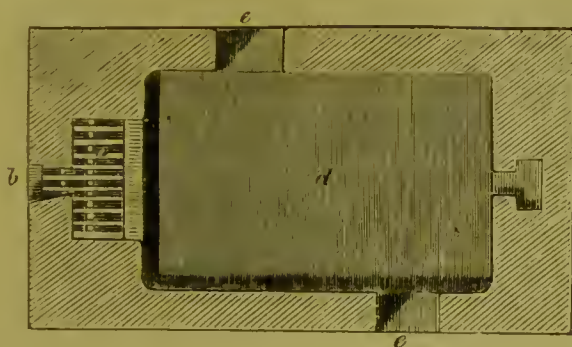
are principally a carbonate mixed with some oxide, having a calcareous and argillaceous gangue; and as

Fig. 630.



the latter ingredients would materially impede the reduction of the principal compound, the oxide of zinc,

Fig. 631.



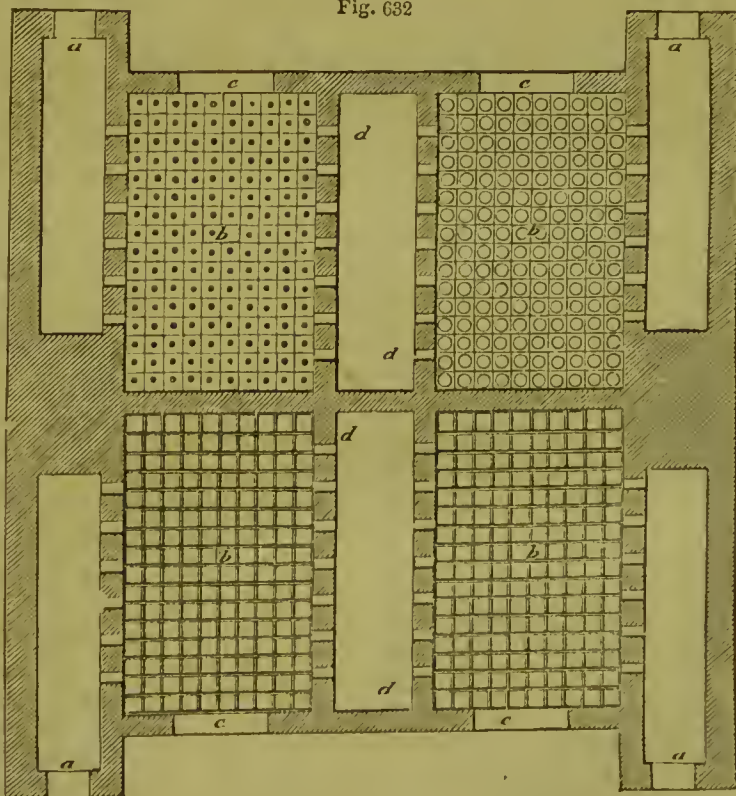
they are as far as possible removed by processes of disintegration and washing analogous to those already mentioned in connection with the Belgian method.

As in the English and last mentioned smelting establishments, the purified calamine is here submitted to a preparatory calcination for the purpose of expelling the water and carbonic acid. The furnace used for this purpose is shown in Figs. 630 and 631. It consists of an ordinary reverberatory, of which *a* is the fire-grate, *b* the doors by which the fuel is introduced, *c* the fire-bridge, *d* the interior of the furnace, the bed of which is constructed of ordinary bricks, *e e* the working doors by which the charge is rabbled and worked during the calcination, *f* the flue leading to the chimney, and *g* the superior aperture whereby the ore is charged upon the bed of the furnace. The latter is lighted in the usual way, and as soon as the interior attains a strong red heat, from thirty to thirty-five hundredweight of ore are introduced at *g*, the workmen spreading it out upon the sole with rakes at the working doors; this done all the openings are closed, and the roasting is allowed to proceed uninterruptedly, with the exception of an hourly rabbling for the purpose of exposing a fresh surface of ore to the flame, till the whole of the moisture and carbonic acid is expelled. The completion of the work is judged of by the apparent heat of the interior of the

furnace, the facility with which the ore falls to powder, and its change of color, which in case of the red calamine being operated upon should be brownish, and of the white calamine brownish-red. When these appearances are observed the charge is drawn, and a second, which had been placed on the platform in the interval between the charging and drawing of the roasted ore, introduced in its stead, the largest fragments from the last operation being ground and added to the fresh ore to be recalcined. Four charges are thus treated in the twenty-four hours, making a total of nearly six and a half tons of ore, which yield about seventy-two hundredweight of calcined calamine, with a consumption on an average of twenty-three bushels of fuel.

The Carinthian Process.—Here the furnaces are worked on the same principle as the English ones, but the details are different:—Figs. 632 and 633 show a plan and sectional elevation of the Carinthian furnace. As at the *Vicille Montagne* smelting works, four furnaces are connected in one block with one chimney; they consist of rectangular chambers arched over at the top, *b b b b*, heated by fires, *a a a*, from which the heated gases and flame enter by openings, *a' a'*, to the space occupied by the retorts. Above the sole of the retort chamber, *b*, is placed a trellace work of iron, in the squares of which the vertical retorts, *p p*, are fixed by means of a clay conductor, *n*, which receives the zinc separated in the vertical cylinder. *c c c c* are the side doors affording ingress for placing the conductors and retorts in position for operations, *et cetera*; *d d*, outlets for the waste gases from the furnace into the flues, *e e e e*, leading to the chimney, *h*. Beneath the conductors, *n n*, is placed a flooring of plate-iron, *r r*,

Fig. 632



resting on cross supports, as well for receiving the zinc which falls in the course of the distillation as for excluding the atmosphere, and thereby preventing

the reoxidation of the metal. Each of the distilling compartments admits of erecting one hundred and sixty-four vertical retorts with their conductors, but the four ranges more distant from the heat contain only

Fig. 633.

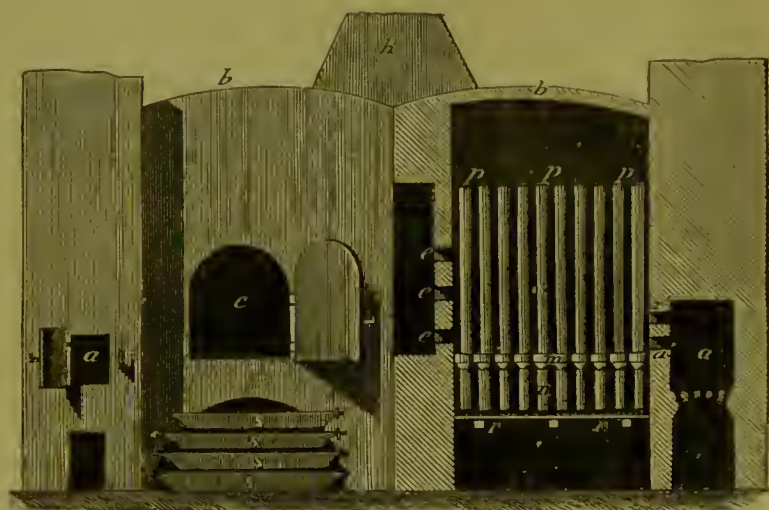


Fig. 634.



Fig. 635.



empty cylinders in process of being baked by the waste heat; and even for those within the range of a distilling temperature a different mixture is made for the charging according as the cylinders are nearer to or more distant from the fire. This mixture has the following composition:—

	For the four ranges nearest the fire.	For the other two ranges.
Roasted calamine,.....	1820 lbs.	520 lbs.
Wood charcoal, ground,.....	504 lbs.	224 lbs.
Common salt,.....	36 lbs.	16 lbs.
Water charged with 1-200ths of potassa,	280 lbs.	70 lbs.

The four first ranges contain sixty-four cylinders, whereas the following two contain but twenty; the remaining spaces being left free for the passage of the products of combustion. Two adjoining furnaces are always worked together, and in these one hundred and sixty-eight cones are in operation. During the course of the distillation, which occupies thirty to thirty-six hours, the consumption of wood as fuel amounts to seven hundred and fifty cubic feet, and the proceeds average eight hundred pounds of metallic zinc.

Considerable loss of time, fuel, and retorts is incurred from the intermittent nature of the process. After collecting the metal which falls upon the plate-iron flooring, indicated by *rr*, in the foregoing figures, it is refined from oxide and other grosser impurities by fusion in pots placed in a furnace, represented in plan and section in Figs. 634 and 635. After melting the metal in the series of pots shown in these furnaces, the scum of oxide, carbonaceous matters, *et cetera*, rises to the surface, and is removed by the ladle, and the purified metal is cast into moulds for the market.

Silesian Method.—In Upper Silesia the reduction of zinc ores is carried on by a distilling process in a muffled furnace, as will be described presently. The principal seat of the smelting is in Silesia, where, in 1848, there were no fewer than thirty-five establishments for the distillation of the metal. In the Rhine Province, at the same period, there were five, and in Westphalia one. With the growing demand for zinc, however, these establishments have, during the last ten years, been enlarged and rendered more effective, so that

Fig. 636.

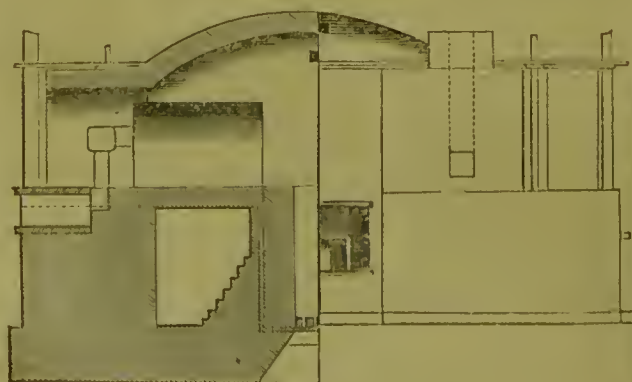
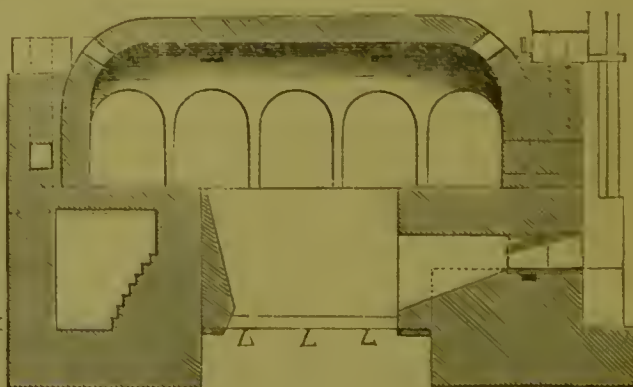


Fig. 637.



their capacity for working is greatly increased. It may be remarked that the *material* of the muffles consists of fire-clay, obtained from Ruda Krzeszowitz and Kattowitz in Upper Silesia, as also from Murau

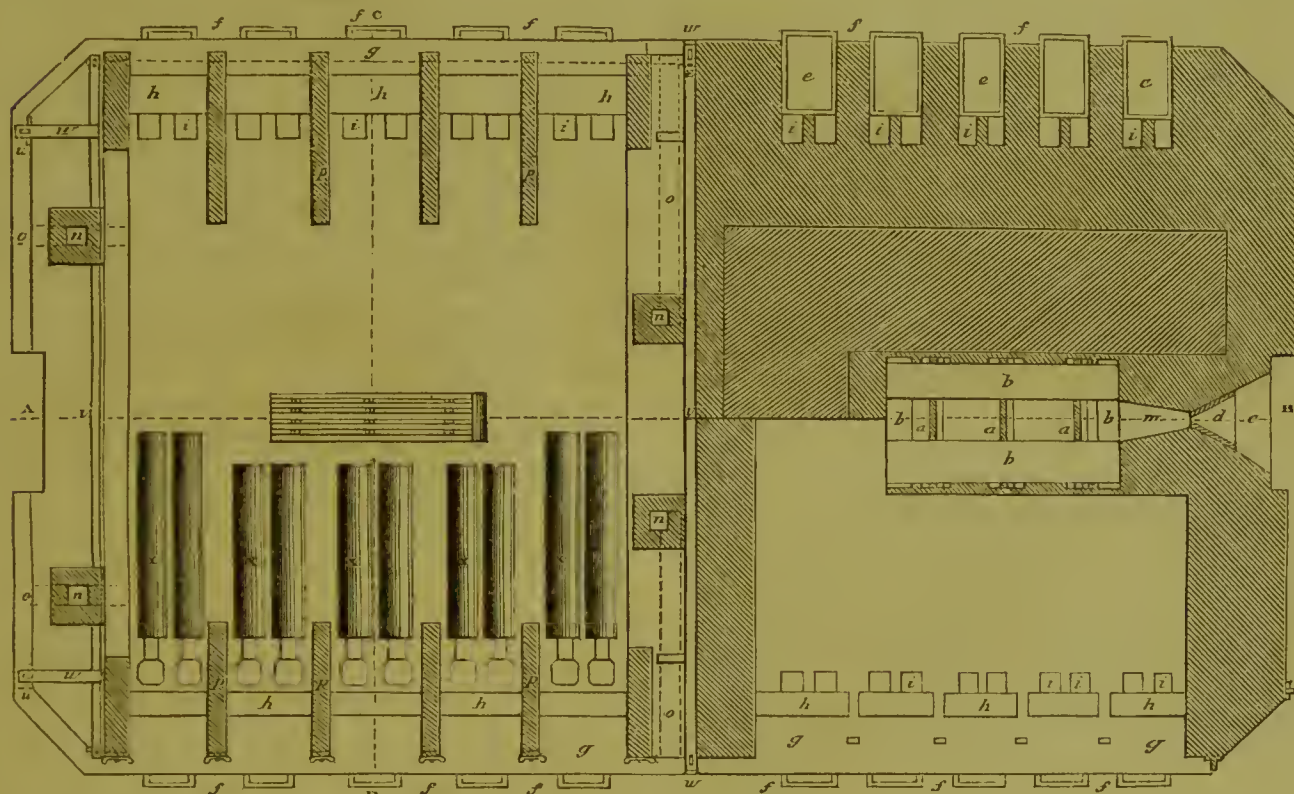
in Poland, and which, after the necessary preparation, is mixed with reduced broken muffles, the whole being properly blended together to give the articles the necessary cohesion and compactness. The proportion of clay and potsherds is invariably two of the former to one part of the latter. These muffles are always made by hand, and submitted to a gradual course of

desiccation, then annealed at first at a very moderate temperature, and finally at a full red heat in a furnace especially constructed for the purpose, somewhat in the manner of making glass-pots.

Figs. 636, 637, 638, 639, 640, represent the ordinary furnaces, called *double ovens*, adopted in Upper Silesia for the reduction and distillation of zinc from its ores.

Fig. 638.

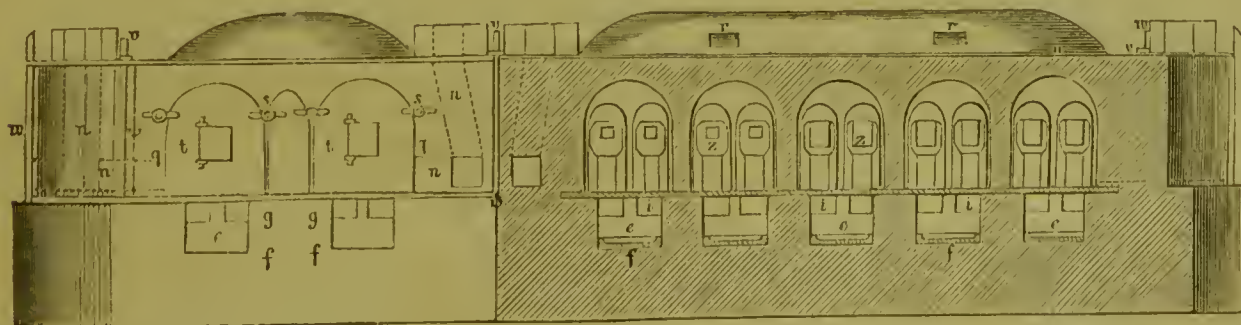
Fig. 639.



They have ten primary large chambers; but these in working are divided into twenty smaller parts, the large muffles being so constructed that the back wall is common to the two ranges. Fig. 636, is a section representing a longitudinal view to the left hand, following the line A B, and to the right the line C D in Fig. 637. Fig. 638 shows a ground plan at $a' b' c' d'$ in Fig. 636, and $d'' d''$ in Fig. 637, in the upper half of the left side, and in the under half at $a' b' c' e'$ in Fig. 636, and $e'' e''$ in Fig. 637. The portion to the right

exhibits the furnace vertically under the dome. The same letters indicate like objects in the several figures. Three triangular cast-iron bars, $a a a$, secured at each end in the walls of the furnace, bear four iron plates, $b b$, laid transversely, to form the fire grate; the whole constituting a rose over the air channel and ash-pit. The fire-door, c , which is lined near the grate with a cast-iron box, d , is closed with a door of plate-iron, the sole of the aperture being likewise secured by a similar plate; $e e$, *et cetera*, are inclosed troughs, into

Fig. 640.



which the distilled zinc trickles from the apertures of the retorts. The base of these is of iron plates, $f f$, to which deep iron bands are fixed for preventing the overflowing of the metal as it falls from the mouths of the retorts opening into them. All these receivers are closed by a single plate, $g g$, extending the whole

length of the oven, and called the *hearth-plate*. They are but one foot wide, and protect, therefore, only the front part of the receivers; the interior of the latter being secured by supplementary closely fitting plates, $h h$, touching the hind part of the openings, $i i$, and towards which is the connection between the dropping aper-

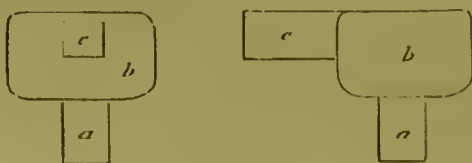
tures and receivers. These hearth-plates, in order that they may not be warped by the heat, are fastened by three cast-iron fluted anchors of the form of the letter Z. The walls, *l*, of the fire-chamber are constructed of the best fire-bricks; the connection between the fire and fire-door being an inclined canal, *m*. The upper rim of the fire-chamber is a few inches higher than the receiving troughs, so that the hearth slightly inclines from the middle to the side walls of the oven. The space between the posterior walls of the two adjoining ovens is filled with sand and rubbish; *n n* are side draughts for heating the rim muffles, and *o o* horizontal entrances for cleaning the same, which, however, are closed during the firing; *p p p*, *et cetera*, are pillars from three to five inches in thickness, constructed of clay, and furnished exteriorly with iron plates, *q*, secured to the hearth-plates, *g g*. These pillars form the support of the arches of the muffles which receive the retorts, as also of the overspanning dome. They should be as low as possible, so that the distance from the apices of the interior arches and the hearth be not more than three feet. The dome of the oven is constructed of a composition consisting of one-third part clay and two-thirds sand; its thickness when dry is eight or nine inches; *r r* are six cap or draught holes, by opening or closing which the heat can be directed towards any of the retorts which should happen to be working unsatisfactorily; *s s* hinges or clasps for fastening the doors, *t t*; *u* long braising bars or anchors; *v* oblique ones, and *w* upright anchors, all applied for the purpose of giving solidity to the oven.

The retorts or muffles, *x x*, are set two and two within the muffle arches in the spaces between the pillars, *p p*, and placed as far back as possible, with their open faces to the front. When placed in their proper positions, the spaces between their walls and the pillars are blocked up with clay cement so as to confine the flame. The mouth of the retort is closed with a piece of clay called the bridge, *y*, and shown somewhat enlarged in Fig. 641. It has two openings; the under one, *a*, closed with a clay stopper during operations, for drawing out the residuary matter of the distillation, and the upper one, *b*, for receiving the neck of the conduit by which the vapors of zinc pass to the receivers. The latter part of the apparatus is seen in Fig. 642; the under part, *a*, is a clay pipe; the upper part consists of the head, *b*, and the neck, *c*. An opening in the head of this receiver serves for introduc-

Fig. 641.



Fig. 642.



ing the small charging shovel—Fig. 643—to spread the charge within the retort. It is closed like the opening, *a*, in Fig. 642, during the distillation.

Before the muffles are placed in the distillatory oven, they are subjected to a strong red heat in the furnace

employed for annealing them. They are then placed two and two in the arched chambers of the zinc oven, and charged with a mixture of sixty-six pounds of

Fig. 643.



roasted calamine and an equal volume of cinders or small coal—forming about five per cent. of the weight of the ore—together with a few pounds of oxide of zinc and abstrich or semioxydised skimmings from the collected zinc. All these are intimately mixed together before their introduction through the upper opening of the muffle bridge, the lower aperture meantime being secured with a plate and lute of clay. When charged, the neck and condenser are fixed in their places, and all apertures and cracks safely coated with luting. The iron doors in front are closed to retain the heat, and the firing proceeded with. Scarcely a quarter of an hour after the closing of the front doors of the muffles elapses when the metal begins to pass over; nevertheless the distillation is not in full activity till six to eight hours after commencing. As in the other distillatory processes already described so in this: the zinc, deprived of its oxygen by the coal in the body of the retort, passes off into the neck and head of the conduit in the form of vapor, and then condensing falls through the descending pipe into the plate-iron receivers. The combustion of a portion of the zinc cannot be avoided, as it is impossible to prevent the admission of some air into the receivers and conduits. It is owing to this, that a portion of white oxide is always found in the receivers, averaging from two to four per cent. of the metal obtained. At the close of twelve hours all the metal is extracted, and a second charge is introduced, without, however, clearing out the residue in the retort until at the end of the second operation, at which period a new bridge plate may be supplied if necessary, or any other repairs made. Care should be taken to change the muffles of both working sides of the oven every six hours after their setting in.

When the calamine contains much cadmium, it is found that the first portions of the distillate are very rich in this metal; and the oxide produced by the combustion of portions of the metal in the neck of the retort is likewise richer in oxide of cadmium, both effects being due to the volatility of the cadmium being greater than that of zinc. Six hundred pounds of roasted calamine are worked off by a furnace of ten large muffles in twenty-four hours, with charges for each retort averaging six pounds. The estimated consumption of coal per every hundred of zinc obtained is twenty-eight cubic feet; the loss of the metal is estimated at eight per cent., and of large muffles twenty-eight for every thousand pounds of zinc obtained. The average produce from the calamine operated on is about fifty per cent. in the form of metal and oxide. But as the ore varies in its content of oxide of zinc, so also does the yield. To purify the metal resulting from the first distillation, it is melted in iron

pots, and the scum of oxide and other impurities separated. This amounts to eight per cent. ; but as it contains about seventy per cent. of metal, and is submitted to a new reduction, a considerable amount of it is recovered.

At Kloster, where blende is worked, the apparatus and system of reduction are the same as that just described, with the exception of the roasting furnaces, in which the sulphide of zinc is converted into oxide. These are also the same as those that have been previously described, and consequently need not be further referred to.

PATENT PROCESSES.—The only patents connected with the manufacture of zinc which are of any importance, are those of TROUGHTON and GRAHAM; the former sealed in 1839, and the latter in 1845. Other patents have been secured, but the Editor deems it unnecessary to dwell upon them.

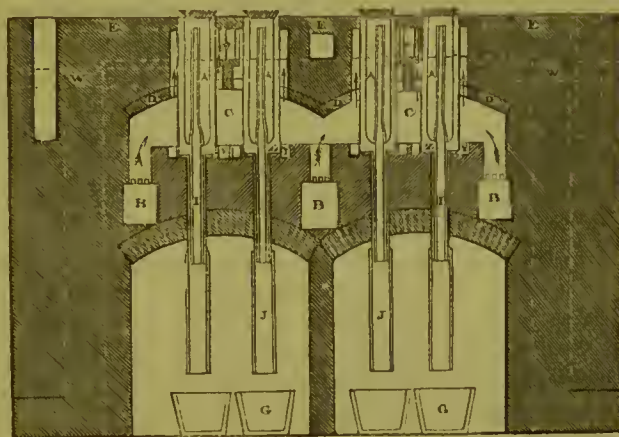
TROUGHTON's patent professed to deal with blende, and prescribes a form of furnace for the roasting, as also for the reduction. The first of these is in form like an ordinary reverberatory, with, however, three floors or hearths, on each of which the ore is spread, the heated gases and flame passing from the under chamber into the middle, and thence to the upper one, after which the gases proceed into the chimney. The connection between the several floors is made by apertures, covered by fire tiles during the roasting, but which are removed when it is necessary to transfer the ore through these openings from the upper to the lower ones. By apertures at the sides the contents of each floor are rabbled in the usual way. The charging of the ore is effected through hoppers at the top, and when roasted it is raked out into receptacles beneath the lowest hearth, by the workable openings already mentioned. A close fire, charged with fuel, which may be anthracite coal, and urged by a blast, affords the requisite heat; the opening for introducing the fuel being secured by a cast-iron cover, with a flange descending into a groove which may be kept filled with water or sand to prevent the escape of hot gases.

The fire by which the smelting of the roasted ore is effected is similarly constructed, and the combustion maintained by a blast of hot air. Though the plan as detailed in the English system is followed, yet the details are very different; the receptacles for the reception of the roasted ore and coal are constructed in the form of a trapezoid, the front part being movable when it is necessary to charge or clean out the retorts; but during the distillation it is securely luted in its place. Two ranges of retorts are placed back to back in a gallery, and the heat from the fire conducted beneath and over them by a proper disposition of the flue; and for the purpose of economizing heat, the patentee directs that the retorts be so fixed that they may be heated by a fire from both ends of the gallery. A pipe opening into the retorts, and leading to receivers in a confined arch beneath the hearth, serves to carry off the distillate or zinc. When charged and in working condition, the retorts are closed in by an iron door before each; the space above the retorts wherein the ore is previously heated, is likewise approached by sliding doors, with the view of

rendering the introduction of ore and its withdrawal more easy.

In GRAHAM's patents, sealed in 1844 and 1845, the system of distillation *per descensum* is adopted; improvements being claimed for the arrangement of the apparatus and furnace, as well as for the method of making the cylinders or retorts in which the decomposition of the prepared ore is carried out. The mixture which the patentee finds most suitable for the body of the refractory cylinders just mentioned, consists of one and a half hundredweight of Ceylon black lead; six hundredweight of Stourbridge clay; and one hundredweight of potsherds. These ingredients should be well pugged and tempered, and cut into pieces of convenient size, care being taken that no excess of moisture be used that would prevent the proper cohesion and tenacity of the mass when ramming it into the mould. Fig. 644 represents the furnace and the position of the cylinders and other objects. A, A, are a series of pots, of which the number shown in the furnace is sixteen, but more or less may be employed, according to circumstances. The heat from the fireplaces, B, B, enters into the

Fig. 644.



arched chambers, C, C, and circulates round the cylindrical retorts let down through the arches, D, D, and thence into the flues, as shown by the arrows, and finally by the openings, F, F, into the chimney. The pots, A, A, rise above the arches, D, D, and pass through the covering of brickwork, E; in like manner their outlet penetrates the bed of the arched chamber of the furnace, and opens into the receivers, G, G, beneath, through movable pipes, J, J, and stationary ones, I, I, the latter are constructed of iron and lined with clay, or have a movable clay cylinder fixed within them; they have an iron flange of two inches built in and through the bed of the furnace, in which is a projecting ring or groove, Z, Z, to receive an iron ring that forms the projecting rim just referred to, and which fits into a corresponding depression in the bottom of the pot, and thereby forms, with the aid of a little luting, a tight joint. Y, Y are rings made of fireclay and potsherds, built into the bed of the furnace, flush on the outside, leaving a space of one inch and a half inside, as shown, to form a seat for the pot. W, W are holes in the walls of the furnace, which admit of making an inspection of the pots when necessary.

In charging the pots, the pipe, J, is stopped from

beneath the furnace, and a man holds steady the internal tube, *n*—which has its top covered—until some of the charge is introduced; the remainder is then filled in without fear of disturbing the position of the pipe. The cover is now placed on the pot and luted, and the plug securing the pipe, *j*, withdrawn, and the distillation allowed to proceed by urging the fires, *B, B, B*. When all the metal has been drawn off, the refuse matter remaining in the pots may be cleared away by removing the cover and the internal pipe, and poking it out through the pipe, *j*, into the subjacent chamber.

In the other details the directions which the patentee gives are analogous to the general routine, already sufficiently described.

Mr. CROCKFORD of Holywell, Flintshire, has latterly patented a method of roasting blende preparatory to its smelting, by which all the sulphur is obtained as sulphuric acid. This he effects by employing a furnace the heat of which passes beneath the floor on which the powdered blende rests. At one end of this furnace, the blende is continually introduced in small portions at a time; and in its passage from this to the discharging end of the chamber, in addition to the heat from the floor, it is acted upon by a current of superheated air, in order to convert the sulphur into sulphurous acid. The eliminated gases may be conducted into an ordinary leaden chamber, and nitrous vapor and steam supplied from other departments in the usual way, to convert them to sulphuric acid.

After the depuration of the zinc distilled from the ore it is sold to the manufacturer, or immediately applied to one or other of the many purposes for which this metal is now so generally used. The working of zinc into useful articles was formerly regarded as a difficult operation, owing to its brittleness when worked at a high temperature; by later improvements, however, it can now be rolled and modelled into any desired shape as easily as any other metal. Preparatory to rolling the zinc, the ingots which come from the smelter are melted in pots placed in a reverberatory, such as is represented in Figs. 630 and 631. The iron pots, which are very thick, are rapidly attacked by the zinc, an alloy of the two metals being formed, which is considerably less fusible than the zinc alone, and therefore adheres to the sides of the melting pot. Besides being less fusible than zinc, it is considerably harder and more brittle, and hence, when a small quantity of it gets diffused through the metal in the casting of the plates, those portions do not laminate under the rollers, but break, and thus a hole is produced. All the fusible metal is first cast into moderately thick rectangular plates, which are passed under rollers of the ordinary kind as they cool. During the lamination it is necessary to heat the metal from time to time to a temperature ranging between 270° and 300° , passing it, after each heating, under the rollers. By repetitions of these operations, and keeping the metal as near 212° as possible, the sheets may be reduced to any degree of thinness. Sheets of zinc, manufactured in this way, are in very extensive use for roofing, and generally for applications requiring much exposure to the influence of the air. The metal is also formed

into water-tanks, baths, spouts, pipes, *et cetera*, and is much used for covering or *galvanizing* iron, so as to render it less liable to oxidize when exposed to the action of the air. It is valuable for the positive plates in galvanic apparatus, for the engraver in the department known as zincography, and latterly it has been advantageously applied in the separation of silver from its alloys with lead.

ALLOYS OF ZINC.—The principal alloys of zinc are those which it forms with copper, iron, and tin. Those with copper, the reader will find described under *Brass*, in the article COPPER, and the others will be briefly described here. With iron zinc forms a hard, brittle alloy, at a moderately low temperature, but in proportion as the amount of one or other of the metals is increased, these qualities disappear, and the zinc retains its ductility, or the iron seems to acquire greater tenacity. The ductile state is exemplified in the ordinary zinc of commerce, which retains a quantity of iron, sometimes from one to two per cent., and the second or tenacious state is well illustrated by the experiments of NASMYTH upon galvanized iron, the results of which showed that this alloy welds well, and is not only fully as ductile as the best iron, but acquires greater strength or tenacity.

The experiments were made with some zinced wire rope, which was worked up and welded into a bar. It was observed that, although the iron wire was quite covered with the zinc, the portion of the latter metal which was retained at the welding temperature of the iron, or even the portion of oxide of zinc produced, offered no impediment to the welding. The metallic bar produced was remarkably tough, silvery-grained, and withstood punching, twisting, splitting, and binding, in a manner which showed that the iron was not only excellent, but actually improved in quality in a considerable degree. Another trial was made by welding a pile of clippings of zinced iron plates, as in the preceding experiment. The presence of the zinc seemed to offer no impediment to the welding of the iron, and the bar produced presented, on being fractured, a beautiful silvery grain, as good, if not superior, in aspect to the finest samples of *low-moor*, or *bowling* iron. Bars or *blooms* of the alloyed iron, rolled into rods and tested in the cable-proving machine, indicated from five to ten per cent. more strength than the best samples of wrought-iron; thus evidently showing that, so far from being injurious, a small amount of zinc alloyed with iron has the contrary effect. Bars of iron, prepared according to the last-mentioned process, were heated to the temperature of welding, as when converting them into sheathing in the usual manner, on drawing them from the fire, a handful of zinc filings was thrown on the welding surface, and the welding proceeded with. In this severe test no apparent impediment to the process resulted, the iron welding as well as if no zinc were present. Judging from the appearance of the metal welded up from the zinc-covered iron scraps, not only as respects its clear silvery aspect, but as to the increase of strength which it exhibited under proof, it may not be unreasonable to infer that some important improvement might be made in the manufacture of iron by the actual introduction of metallic zinc in some one or other of the

stages of its production; as, for instance, in the puddling furnace. What may be the nature of the action of the zinc has not yet been defined, but the foregoing experiments prove that, so far from being prejudicial to the quality of iron, the zinc appears to have rather an improving effect, and that to such an extent as to lead to the hope that some of the intelligent iron manufacturers may give the inquiry attention, so as to prove by experiment in the puddling furnace, or at any other stage of the process, whether the benefits above mentioned can be realized on a large scale. It may be stated, as a curious corroborative fact, that the strongest cast-iron made in Belgium, and selected for the manufacture of guns, is made from an iron ore in which a compound of zinc forms a considerable portion. Whether the superiority of this iron is due to the presence of zinc, is a question; but the results above detailed would tend to lead to the supposition that such may be the case.—*Ure*.

The results of NASMYTH, recorded above, are opposed to those of GEHLEN, who states that when cuttings of zinc and iron are ignited together, part of the zinc evaporates, while the rest penetrates the iron and makes it denser and very brittle. Doubtless the difference in the results must be attributed to the relative proportions of the respective metals in the alloy. The hard, brittle compound of zinc and iron produced in the pots where zinc has been melted for a long time, or in which the zincing of iron plates has been effected, was examined by BERTHIER, who describes it as a bright crystalline body, having a mammillated texture, and composed of concentric layers, very hard and brittle, and less fusible than pure zinc. It dissolves readily in dilute nitric acid, and leaves a micaceous residue of a non-metallic nature, which he terms pure plumbagine, produced, doubtless, either from the carbon employed in the reduction of the zinc ores, or from the cast-iron of the pot. Its density was 6·7, and its composition—

	Centesimally,
Zinc,	91·76
Iron,	5·00
Plumbagine, or graphite,	0·24
	100·00

Galvanized Iron.—The composition which forms such an extensive article of commerce and general application in the construction of corrugated roofing, and, in fact, entire buildings, spoutings, ships' sheathing, buckets, and various articles in household use, consists of iron plates coated with zinc, and sold under the above inappropriate title. Iron, though possessing so many admirable qualities, such great tenacity, infusibility, and the very important one of welding, is, unfortunately, rapidly acted upon by air, moisture, and dilute acids, to such an extent as greatly to impair its utility. It possesses the property, however, of combining with other metals, and hence it can be readily coated with such; but those metals which possess the persistent qualities that iron wants, are too dear, and therefore their general application is opposed by the great expense which their use would involve the manufacturer and consumer. Coated iron is familiar to most

people in the form of tinned iron plates, or *sheet tin*; but even this material would be too expensive for many of the applications in which iron might be employed with advantage could its oxidizing tendency be overcome. Zinc offers a cheaper substitute, and of late years the production and application of galvanized iron is on the increase. Although MELOUIN discovered the method of preparing zinced or *white iron* so early as 1742, still its application did not receive much attention, till of late years SOREL drew attention to the manufacture; but MELOUIN's directions, with slight modifications, are followed even at present in the manufacture of this article. The iron to be covered is deprived of its coating of oxide by an acid bath, composed of sulphuric acid and water, or of hydrochloric acid, or a mixture of equal volumes of the two acids and water, in which it is immersed for a short time; it is then scrubbed with sand or emery powder until the surface is cleaned; after which it is immersed in a concentrated solution of chloride of ammonium, taken out, and subsequently introduced into a bath of melted zinc, covered with fatty matter, or colophony, to prevent oxidation, and stirred in it till the zinc forms an alloy at its surface. The coated metal is then, in some instances, introduced into a second bath consisting of melted tin, such as is used for tinning thin sheet-iron, when a slight coating of tin is formed on the exterior of the plate or bar. Of late years this second bath is generally dispensed with, a few pounds of tin being added to the zinc bath to produce the same effect.

According to MALLET's specification, the plates or bars are immersed in a cleansing bath, composed of equal parts of sulphuric acid, hydrochloric acid, and water in a warm state. After immersion the scales are detached by hammering and scrubbing the plates with emery and sand, and a thoroughly clean surface produced. It is now to be immersed in the preparing bath, composed of a saturated solution of chloride of zinc and sulphate of ammonia; after which it is transferred to a bath formed of six parts and a half of zinc and one of mercury, heated to the melting point of the former metal; in addition to which the patentee directs the addition of one pound of potassium or sodium to every ton of the preceding amalgam. When the immersed iron has attained the temperature of the bath, namely, 680°, it is withdrawn, and is found coated with a metallic layer, of which zinc forms the principal constituent. The affinity of the above alloy for iron is so great that it entirely disintegrates the iron plates, or other articles of this metal when they are thin, or possess but little body; and to guard against this inconvenience, the patentee suggests that some wrought-iron should be allowed to dissolve in the triple alloy previous to the introduction of small articles, such as wire, nails, light chains, and similar objects for galvanizing. Another means of coating iron with zinc is by electricity, and the use of a bath formed by the solution of freshly precipitated oxide of zinc in a saturated aqueous solution of sulphurous acid, or of that of the double chloride of zinc and ammonium. A moderately dilute bath and a weak current answer best. This method is not advantageous in a manufacturing sense,

the simpler mode of immersion being more expeditious and less costly.

Though iron coated with zinc is unquestionably better calculated to resist atmospheric influences without rusting than when it is without such covering, still zincing it is very far from being a uniformly successful protection against its oxidation, and in some cases it increases rather than diminishes this tendency of the iron. Professor CALLAN proposed an alloy of lead and antimony as a substitute for the zinc; but though the disadvantage experienced in many instances as resulting from the employment of zinc are certainly diminished by the use of the alloy, still the cost of the latter precludes its adoption.

Applications of Zinc.—Besides its long-practised application in the production of brass and other alloys, such as German silver, tutenag, *et cetera*, which the reader will find described under COPPER, zinc has been employed extensively in the form of sheets for the manufacture of baths, water tanks, buckets, pails, roofing, spouts, pipes; as a cheap and more durable substitute for sheet and japanned iron, such as architectural ornaments, street lamps; and for making nails, bolts, wire for preserving iron, applied in the form of wire plates to the numerous uses which are everywhere to be witnessed; as a substitute for bronze in statuary, for which purpose it has been found, irrespective of its color, to answer exceedingly well. It is also extensively employed for the positive plates of electrical batteries, for engraving music, in anastatic printing, and numerous other forms, alone and compounded with other metals. In its oxidized and salified state it has another extensive field of application, both in the industrial arts and in medicine, as will be noticed afterwards.

Assay of Zinc Ores.—The estimation of the amount of zinc in any of its ores by the dry method of analysis, is exceedingly difficult. As, however, the metallurgist may desire to have an approximation of the quantity of metal which he can probably extract from any ore, the following brief statement of the operation is submitted here, reserving fuller instructions for the analysis of zincous bodies in general for the end of the article.

BERTHIER, who has made numerous experiments on the subject of the assay of zinc ores, divides the latter into four classes, for each of which a particular method must be pursued. These are, firstly, ores in which the zinc exists as *oxide*, or *carbonate of the oxide*; secondly, those in which the zinc exists wholly or in part as *silicate of the oxide*; thirdly, ores in which the zinc is entirely or in part in the form of *sulphide*; and fourthly, *alloys* of zinc.

To reduce ores of the first class, it is only requisite to mix them intimately with charcoal, and expose the assay for a sufficient time to a white heat in an earthen retort, having a long neck kept sufficiently cool to condense the metallic vapors that are expelled by the heat from the reducing mass. Care must be taken that no air be admitted into the retort, for this would induce the combustion of the metal while in a state of vapor; its neck should therefore terminate in a small opening, or an adaptor of glass drawn to a point be fixed to it

by luting. During the reduction the following simple interchange takes place:—



Even when the reduction is thoroughly effected, it is most difficult to detach the incrustation of metal sufficiently complete for accurate determination. To facilitate this the neck of the retort is coated internally with plumbago to diminish the adhesion of the distilled zinc to the body of the apparatus. When all the metal is reduced and driven over, the assayer is often necessitated to break off the neck of the retort to enable him to collect the metal, and not unfrequently to dissolve the adhering particles with nitric acid, and evaporate and calcine the residue, adding the four-fifths of its weight to that of the metal already estimated.

Another process by which the estimation of the zinc may be indirectly made is given as follows:—A certain portion of flux is added to the weighed ore, submitted to the test, and the whole heated at the temperature at which the assaying of iron is usually conducted in a lined crucible. The button of slag containing granules of iron resulting from the ferruginous matter in the ore, is weighed, then ground in a mortar, and the iron separated by a magnet, likewise weighed. After deducting the iron thus estimated from the total weight of the button of fluxed matter, the remainder is added to the oxide of iron, corresponding to the amount of this metal found as above. The combined weight, deducted from that of the dry ore and flux, leaves a difference corresponding to the zinc expelled during the assaying in the fire. Again, if the quantity of the fixed flux employed be taken from the weight of the button of slag obtained minus the iron, the difference will show the silicious, earthy, and other unreduceible matters associated with the zinc.

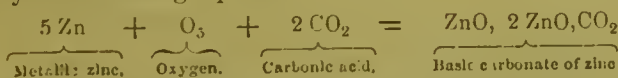
In the examination of ores of the second class, charcoal alone is insufficient to effect the decomposition, and therefore a flux is employed which, by combining with the silicious matter, liberates the oxide of zinc, and renders it subject to reduction by the carbonaceous matter. Lime or magnesia are the agents usually adopted.

When ores of the third class are under examination, the weighed sample is roasted, to convert the whole of the sulphur into sulphuric acid and partly expel it by the heat; after which the reduction is effected in the same way as directed for the determination of the metal in the first class of ores.

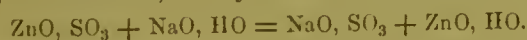
Alloys of zinc with fixed metals, or the compounds of the fourth class, are examined by adding a determined weight of fixed flux, mixed with some charcoal, and heating in a lined crucible at the temperature of the iron assay; all the zinc is volatilized, and from the loss of weight so sustained the amount of zinc is estimated approximately. If the alloyed metal be of a volatile nature, this course will not afford true results, and the estimation of the constituents of the compound must be effected by the humid assay, which indeed is the most trustworthy, and in the end the most expeditious for the analysis of all zincous compounds.

COMPOUNDS OF ZINC.—Zinc is capable of uniting with almost the whole of the metalloids and salt radicals, producing compounds, which in all instances are of great importance in the arts, and have consequently a very extended application. Its oxygen salts, like those of magnesia, have the property of forming saline compounds with other substances, the importance of which is entirely confined to the department of scientific chemistry connected with stoichiometry. Another remarkable behavior of zinc is, that it readily combines with several organic radicals, such as ethyl, methyl, and radicals of the alcoholic series of compounds, as shown by the very scientific researches of FRANKLAND and others. Several of the combinations of this metal are employed in medicine; and, by a remarkable coincidence, these so employed are most useful in many industrial applications. It will be sufficient to describe here the oxide, the carbonate, sulphate, acetate, and chloride of this metal.

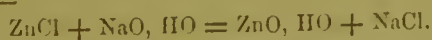
OXIDE OF ZINC.—This compound has various designations, most of them given by the alchemists. Its ancient synonyms were *nihil album*, *lana philosophica*, *flowers of zinc*, *pompholyx*, and occasionally it is still known as *flowers of zinc* or *flores zinei*. When submitted under certain circumstances to the influence of air and moisture, zinc is acted upon in various ways, all of which result in producing the oxide, or a compound from which the oxide can be readily prepared. Thus, when the metal is heated to redness in a free current of air, it burns with a brilliant bluish-green flame producing oxide of zinc. Again, if the zinc be exposed to air and moisture, it is transformed into the same compound; or if carbonic acid should be present, into a basic carbonate of the oxide. In these cases, simple and direct oxidation takes place, the oxide combining, in the latter instance, with a certain amount of carbonic acid. This is the nature of the change which is produced on the surface of zinc exposed to the air, as in roofings, *et cetera*, and which conduces so much to its preservation. It is illustrated by the following equation:—



When zinc is dissolved in sulphuric or nitric acid, the oxide is freely formed, though only in the proportion requisite to produce a salt with the acid employed. In this state it exists in the salified state, but on abstracting the acid by interposing a stronger base, such as soda, the hydrated oxide falls, thus—



The same change takes place when the solution of zinc in hydrochloric acid is acted on, although the oxide does not pre-exist in the menstruum, for at the period of the removal of the radical of the salt the oxygen of the precipitant is assimilated by the zinc, as shown in the equation—



Oxide of zinc is prepared either by the ignition of the metal in a current of air, or by its solution in acids and subsequent precipitation by any convenient agent. If pure oxide be required, the first method will not yield it unless the metal be free from all extraneous metalliferous

matters, which is never the case with the commercial article. In the second method the impurities existing in the zinc can be removed previous to the precipitation of the oxide, and consequently this method is preferred when it is important that no foreign matter should exist in the preparation.

In operating by the first method, a hessian crucible is filled with zinc to one-eighth its capacity, and then placed in a wind furnace so inclined that the lower part rests upon its edge on a piece of tile at the bottom, whilst the upper part is supported by the rim of the furnace. The fire is then urged till the crucible and contents attain a strong red or white heat. At this period a scum of oxide appears on the metal, and must be removed with an iron spatula as fast as formed, till the combustion of the zinc is completed, when a fresh charge may be introduced. The oxide as collected is placed upon an iron plate to cool, and is afterwards rubbed up with water to the consistence of a thin pasty mass, which is next diluted largely, allowed to settle for a few minutes and then decanted, more liquid being agitated again with the subsided matter, and treated, after a minute or two's repose, in the same manner. By continuing the treatment so long as the decanted liquors flow off milky, all the oxide is separated from the metallic matter which escaped ignition in the crucible, and which may be introduced with another portion of zinc to undergo fresh combustion. All the decanted liquors are collected together and allowed to subside perfectly, when the clear water is poured off, the deposit thrown upon a cloth filter to drain, and finally it is dried at a gentle heat. The yield of zinc oxide obtained in this way, when the whole of the metal is burned, will be somewhat more than the weight of the zinc employed.

When the oxide is to be prepared by the liquid process, rectified sulphuric acid, diluted with ten times its weight of water, is poured upon the zinc previously rolled into thin sheets, or granulated by pouring it whilst in a molten state into a vessel of water, employing an excess of the metal with the view of causing the foreign matters, such as lead, tin, cadmium, bismuth, arsenic, *et cetera*, to be precipitated; or a solution of crystallized sulphate of zinc in thirty parts of water may be taken, immersing in it for forty-eight hours a few thin plates of zinc, which act in the removal of any foreign bodies in the same way as the excess of metal in the foregoing method. The clear solution is decanted in either case, or strained, if necessary, and a hot concentrated solution of carbonate of soda is added to it as long as a precipitate forms. This precipitate, which settles much more readily when thrown down from hot solutions than from cold ones, is now washed with hot distilled water by decantation, till no further trace of sulphuric acid is detected in the washings with a solution of chloride of barium. After thorough washing it is collected on a cloth filter, allowed to drain, pressed and dried, and finally heated to redness in a hessian crucible, till the whole of the carbonic acid is expelled, as evidenced by its not effervescing on the addition of dilute acid.

Properties.—Oxide of zinc is a white, tasteless, inodorous powder, which at red heat acquires a yellow

color, that vanishes on cooling. When subjected to a higher heat it melts into a yellow glass, and at a sustained white heat volatilizes. It is insoluble in water, but readily soluble in acids, giving rise to the corresponding zinc salts. When freshly precipitated, oxide of zinc is readily soluble in alkaline solutions, as also in concentrated ones of sesquicarbonate of ammonia, producing compounds in which it assumes the characters of a salt radical that are called *zincates*. Heated with charcoal it is readily reduced to the metallic state.

Uses.—Oxide of zinc is employed principally in medicine. Latterly, however, it has been successfully introduced as a substitute for carbonate of lead—white lead—in the manufacture of paint; and to meet this extended use several processes have been devised for its preparation, to which reference will be made presently. The oxide has been prescribed in some cases of epilepsy, chorea, hysteria, catalepsy, and whooping-cough, as well as in some painful affections of neuralgia and gastrodynia, with occasionally good effect, though its frequent failure has shaken the confidence of practitioners in its efficacy. It has been found serviceable in five-grain doses, combined with extract of henbane or hemlock, in colliquative perspiration. It is useful as a desiccant to allay or prevent excoriation in children, as well as in cases of chronic skin diseases, attended with profuse secretion, and also in other ailments of a similar nature. In large doses, oxide of zinc acts as a slight irritant and causes vomiting, and by long-continued use it acts as a slow poison.

Oxide of zinc is composed of—

	Atomic weight.	Centesimally.
1 Eq. of zinc,	32.0	80.0
1 Eq. of oxygen,	8.0	20.0
	<hr/> 40.0	<hr/> 100.0

Its chemical symbol is ZnO.

CHLORIDE OF ZINC—*Muriate of zinc; butter of zinc.*

—This compound of zinc has long been known and applied in medicine. It is prepared by adding hydrochloric acid of specific gravity 1.130 to granulated zinc portionwise, and applying heat till the latter is dissolved. Four parts and a half of acid are required for every part by weight of metal for its perfect solution. A few fragments or thin plates of zinc are introduced into the solution, and set aside for twenty-four hours, during which time any lead, tin, antimony, cadmium, or other metals of this class that may be present in the liquid, are precipitated; after this, the clear liquid is separated by filtration from the deposit that may have formed, and about one-sixteenth of its bulk precipitated, with a very slight excess of carbonate of soda, the basic carbonate separated and well washed while on the filter, and then introduced into the remainder of the liquid. Chlorine, generated in the usual way from bin oxide of manganese and hydrochloric acid, is now passed into the menstruum till it smells of the gas. A further period of twenty-four hours is given to the liquid to stand, and if, after this period, a portion of the clear solution exhibits any indication of the presence of iron, either by giving a bluish-black color with tincture of galls, or by striking a deep blue with ferriyanide of potassium—red prussiate. A further

portion of the liquid is taken and precipitated with carbonate of soda, as above, and the mass so obtained, after thorough washing, is added to the liquor containing the zinc, allowed to digest for a further period, and afterwards tested for the presence of iron in the manner indicated. If necessary, the process is to be repeated a third and a fourth time, or until the whole of the iron is separated in the form of sesquioxide; but it rarely happens that this metal remains after the second digestion. After filtering from the formed deposit, the liquid is evaporated in a porcelain or hard stoneware dish on the sand-bath, taking care, as it becomes denser, to keep the contents of the vessel constantly stirred, till the whole of the water is expelled. Chloride of zinc remains, and should be transferred, whilst still hot, to well covered vessels for use. When it is necessary to deprive it of the whole of the water, the residue from the evaporation should be introduced into a glass vessel with a narrow neck, and heated at a higher degree, till the chloride of zinc begins to distil, at which period the fused matter is poured out on a slab, and when cooled broken into fragments, and preserved in well-stopped bottles.

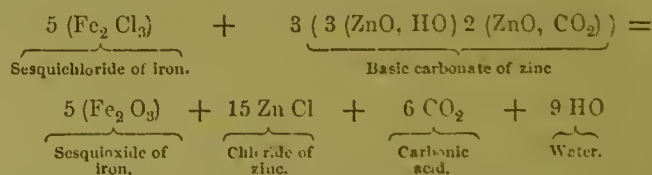
In the preceding process the action of the acid is simple and well understood, its chlorine uniting with the metal, while its hydrogen is disengaged, thus—



The action of the chlorine is to convert the iron, which always exists in commercial zinc, from the state of protochloride to which the hydrochloric acid reduces it, to that of sesquichloride, as shown in the equation—



with the view of precipitating it subsequently with the basic carbonate of zinc— $3 (\text{ZnO}, \text{HO}) 2 (\text{ZnO}, \text{CO}_2)$ —produced by the carbonate of soda in the portion of the liquid submitted to its action. The manner in which its separation is enigmatically effected may be represented thus—



that is, three equivalents of the basic carbonate convert five of the iron salt into five equivalents of insoluble sesquioxide, being themselves reconverted into fifteen equivalents of the chloride of zinc by the assimilation of the chlorine from the iron compound.

Chloride of zinc may be prepared by other processes, such as heating equivalent weights of oxide of zinc and chloride of ammonium, or by distilling a mixture of dry sulphate of zinc and chloride of sodium in a retort, the substances being employed in the ratio of their equivalent weights. In either case chloride of zinc results, the change in the former being $\text{NH}_4 \text{ Cl} + \text{ZnO} = \text{NH}_4 \text{ O} + \text{Zn Cl}$; and, in the latter, $\text{ZnO}, \text{SO}_3 + \text{Na Cl} = \text{Zn Cl} + \text{NaO}, \text{SO}_3$. The salt in the first formula remains after the expulsion of the ammonia; but in the second instance it distils over, leaving the

sulphate of soda in the retort. Preference is, however, generally given to the method of preparation by solution.

Properties.—Chloride of zinc, deprived by fusion of all moisture, is a whitish-grey, semitransparent soft mass, like wax, that melts at a temperature below redness, and at a higher degree of heat sublimes, being at the same time partially decomposed into a basic chloride of zinc and an acid salt, which collects in crystalline needles in the receiver, and oxide of zinc retaining a little of the chloride that remains in the retort. Exposed to the air, the salt rapidly attracts moisture and deliquesces. It has a burning, nauseous, saline taste, even in highly dilute solutions. Alcohol and ether readily dissolve it, the solutions manifesting an acid reaction. It unites with chloride of ammonium and chloride of potassium, and forms definite compounds with them, likewise with albumen and gelatin, producing difficultly soluble precipitates. The alkalies and alkaline carbonates decompose it, giving rise to precipitates of oxide and basic carbonate of zinc, according to the agent used, but which precipitates, as stated under *Oxide of Zinc*, are soluble in an excess of many of these reagents, owing to zincates of those bases being formed. Sulphuric acid readily converts the chloride into a sulphate of zinc, with evolution of hydrochloric acid. The pure salt has a composition corresponding to the symbol Zn Cl , being composed of—

	Atomic weight.		Centesimally.
1 Eq. of zinc,.....	32.0	....	47.407
1 Eq. of chlorine,.....	35.5	....	52.593
	67.5	....	100.000

The composition of the hydrated salt is Zn Cl, HO ; it is crystalline, and contains, according to SCHINDLER, in one hundred parts—

	Centesimally.		Schindler.
Zinc,.....	32.0 = 41.83	....	39.80
Chlorine,....	35.5 = 46.40	....	43.81
Water,.....	9.0 = 11.77	....	16.39
	76.5	100.00	100.00

Uses.—Owing to its physiological effects, the chief use of chloride of zinc is in medicine; but latterly it has been successfully introduced as a disinfectant, and likewise for impregnating wood in order to preserve it from decay or putrefaction. Its use has been much extended in the first application by its qualities as a caustic or escharotic, destroying the life of the part with which it comes in contact, owing to its combination with the albumen and fibrin of the tissue, which substances appear in the form of an eschar some time after. Many prefer chloride of zinc in this capacity to nitrate of silver, and even to chloride of antimony, as it penetrates further, and leaves the wound or sore in a more healthy state after the removal of the eschar. When taken into the system, chloride of zinc acts, in large doses, as an irritant or caustic poison, and affects the nervous system. It produces a burning sensation in the stomach, nausea, vomiting, anxiety, short breathing, cold sweats, fainting, and convulsions. In very small doses, none of these effects are attendant upon its use.

Sir WILLIAM BURNETT introduced a concentrated
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solution of this compound some years ago, as a disinfecting and antiseptic fluid. The liquid contained about one-fourth of its weight of the salt, and had a specific gravity of 2.0. Its antiseptic qualities depend upon its power of uniting with animal tissues, and forming permanent bodies with them; and hence its use in preserving anatomical subjects for dissection; its disinfecting quality arises from its power of decomposing sulphide of ammonium and sulphide of hydrogen to some extent. It is inferior, however, in this respect to a solution of chloroxide of calcium—bleaching powder—and several other combinations, as stated under *Disinfectants*—owing to the latter being not only capable of arresting gaseous emanations, but also of disseminating a disinfecting gas into the air which arrests any foul odor immediately.

SULPHATE OF ZINC—Zinc vitriol; white vitriol.—This salt, which is said to have been known at the end of the thirteenth century, has been long manufactured on a large scale at Goslar in Germany. It was long erroneously considered as a modified sulphate of iron, but this notion was abandoned when the true metallic nature of zinc became known. It is much more important than any other saline combinations of the metal, as well for its cheapness as for being the means of preparing the other compounds of zinc, and likewise for the extended uses to which it is applied in the arts and in medicine.

Preparation.—At Goslar, where sulphate of zinc was first extensively manufactured, as well for the preparation of Nordhausen vitriol as for application in the medicinal art, the following process was adopted:—

The natural deposit of ore, consisting of sulphates of zinc, lead, copper, silver, and iron, was assayed to obtain the portions richer in zinc; these were submitted to a roasting operation in heaps, during which the sulphur was converted into sulphuric acid, and by this the metals were changed into the corresponding sulphates; the mass was then lixiviated, and the soluble salts, consisting of sulphates of zinc, iron, cadmium, copper, and silver, washed out, and afterwards evaporated till the sulphates crystallized. The impure salt, after slight washing, was heated to the melting point, and the whole, or chief, part of its water of crystallization expelled. On allowing the mass to cool at this stage, it formed a white opaque granulated substance resembling sugar. At a later period this product was freed from portions of its impurities by re-solution in water, and introducing into the liquor fragments or plates of zinc, which were allowed to remain in contact with it for a longer or shorter time. After drawing off the clear liquid, it was evaporated, and the zinc salt crystallized out as before. This method is still practised, not only at Goslar, but in several other localities where blende is abundant.

Sulphate of zinc is obtained at present as a secondary product from the acid liquors of galvanic batteries employed in developing electricity, as also from the liquors remaining after the precipitation of copper on the large scale from its solutions, by metallic zinc.

The pure salt may be obtained by treating commercial, or purified zinc, in a divided or granulated state, with sulphuric acid diluted with fifteen times its weight

of water, in a leaden vessel, using the acid while still warm; three parts of rectified acid of specific gravity 1.84, are required to convert two parts of the metal into a sulphate. The mixture is sustained at a gentle heat in order to promote the solution, and with the same view the contents of the vessel are agitated occasionally. After the solution is effected, a quantity of metal, about one-eighth of the portion dissolved, is introduced into the liquid, and left to repose during thirty to forty-eight hours, the slight heat being still maintained. By this treatment the lead and other less oxidizable metals are precipitated, and are separated by filtering the liquid while still hot. The filtrate is now largely diluted with water, and a portion of it taken, precipitated with carbonate of soda, as stated under the preparation of chloride of zinc, filtered, washed, and added to the remainder of the solution of the sulphate. Chlorine is then transmitted into the mixture till the protosalt of iron present in it is converted to a sesquisalt; after which the whole is allowed to stand till the iron falls in the form of sesquioxide. The various changes by which the purification of the salt is effected in this instance, are analogous to those specified under *Chloride of Zinc*, and therefore need not be detailed. After filtering the liquid from the deposit of sesquioxide of iron, it is evaporated till a pellicle begins to form on the surface, when it is permitted to rest to allow the salt to crystallize. A second crystallization removes all traces of impurities, but this is rarely required.

Properties.—Sulphate of zinc crystallizes in colorless, transparent, right rhombic prisms, containing seven equivalents of water of crystallization. In this state it is very soluble in water, requiring somewhat less than its weight of cold, and considerably less than its weight of the boiling liquid; thus, according to KARSTEN, one thousand parts of water at 63.6°, dissolve nine hundred and twenty-three parts of this salt, forming a solution, the specific gravity of which is 1.4353. DUMAS states that one hundred parts of water, at the ordinary temperature, take up one hundred and forty parts of the sulphate; while other authorities assert that not less than two and one-third parts of water are necessary for the liquefaction of one of the salts, which is evidently erroneous. Boiling water takes up a much larger quantity of the salt, and even alcohol dissolves traces of it. Sulphate of zinc, according to the circumstances under which it is prepared, is found associated with different quantities of water of crystallization, varying from one to seven equivalents; but the compound crystallizing from its solutions at temperatures below 80° to 86°, always assimilates seven equivalents of water. This salt effloresces slightly in the air; exposed to a heat of 212° it loses 37.3 per cent. of moisture, or six equivalents, the last equivalent being obstinately retained till the heat rises to 451°. By the sudden application of a high temperature the compound at first fuses, and after the expulsion of the contained water, decomposition of the salt follows; anhydrous sulphuric acid, sulphurous acid, and oxygen being eliminated, while a highly basic salt remains. On continuing the heat, however, till it approaches to whiteness, only pure oxide of zinc is left. Heated with charcoal at a red

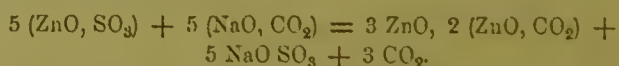
heat, it is reduced to the form of sulphide; but at a sustained white heat, the metal is isolated and volatilized in the form of vapor. Anhydrous sulphate of zinc, on being exposed to moist air, readily assimilates its full complement of water of crystallization with reagents. It affords the usual reactions of oxide of zinc in a salified state, and is capable of forming numerous double salts with other bodies. Sulphate of zinc, in its crystallized form, is represented by the formula $\text{ZnO}, \text{SO}_3, 7 \text{HO}$, and is composed of—

	Atomic weight.	Centesimally.
1 Eq. of oxide of zinc,.....	40.0	= 27.72
1 Eq. of sulphuric acid,.....	40.0	= 27.972
7 Eqs. of water,.....	63.0	= 45.656
	143.0	100.000

Uses.—This salt is used in medicine, in consequence of its physiological effects, which are, when administered in small doses, of an astringent, antispasmodic, and tonic nature; whilst taken in large quantities it is poisonous, causing vomiting, purging, coldness of the extremities, and a fluttering pulse. In full doses it acts as a safe emetic, but care should be taken that it be thrown off the stomach, for if retained for any length of time it occasions nausea and prolonged retching. In this capacity of emetic it is of great use where poisoning is suspected, as it acts rapidly. Sulphate of zinc is frequently used, owing to its astringent and caustic properties, in diseases of the eyes, and generally with good effect. In some cases it is used by dyers as a mordant; also as an *oil drier* for painting.

CARBONATE OF ZINC.—The preparation of the neutral carbonate of oxide of zinc is somewhat difficult, owing to the feeble affinity of the oxide for carbonic acid. If, however, the precipitate which occurs on adding a solution of bicarbonate of soda or of potassa to a solution of zinc be, after washing, disseminated in water, and carbonic acid charged into the liquor, the precipitate is dissolved in the form of a bicarbonate, and on evaporating the liquid in an atmosphere of carbonic acid, the neutral or monocarbonate of oxide of zinc is obtained. Its formula is ZnO, CO_2 .

The ordinary carbonate of this oxide is a basic compound, containing five equivalents of base to two of acid. It is obtained by adding a solution of carbonate of soda to one of sulphate of zinc, taking care that the latter is in slight excess. The change which succeeds may be exemplified thus—



When the precipitant is in excess, a portion of it combines with the basic salt and cannot be removed by washing. For this reason carbonate of ammonia is sometimes preferred, only an equivalent quantity being employed, so that excess of the salt, which would dissolve a part of the zinc carbonate, is avoided. The precipitate in either case is washed well and dried at 212°.

Properties.—It is a loose white powder resembling the carbonate of magnesia of the shops, almost insoluble in water, easily soluble in acids with evolution of carbonic

acid, and converted by a red heat into oxide of zinc. Like the oxide it is readily reduced by carbon at a red heat. MOORE asserts that several of the varieties sold in the shops as calamine or carbonate of zinc contain no zinc whatever, but mixtures of carbonate of lime, sesquioxide of iron, and sulphate of baryta. When a sample of the zinc carbonate is suspected to be fictitious, its purity is readily ascertained by dissolving it in dilute hydrochloric acid, and adding an excess of carbonate of ammonia to the liquor. It should be wholly soluble in the acid, and the precipitate at first formed in the second case should be dissolved by the excess of the ammoniacal salt. A residue on the one hand, or a persistent precipitate on the other, indicates adulteration.

Uses.—Physiologically the carbonate of zinc has the same properties as the oxide, and is applied medicinally in like cases. In the arts, this compound has of late years, together with the oxide, acquired some importance as a substitute for white lead in painting.

ACETATE OF ZINC.—The reader will find this salt described in Vol. I. page 48. It may be stated here, however, that it can be conveniently prepared from the carbonate of this base and acetic acid. Two parts of the carbonate are heated with successive portions of acetic acid of specific gravity 1.045—containing sixty-four per cent. of water—till complete solution is effected. About five parts of acid are required. The solution is filtered while warm, and set aside to cool for a day or two, after which period it is decanted and concentrated to the crystallizing point, when, on cooling, the acetate will deposit. Acetate of zinc possesses a slight odor of acetic acid and a bitter saline nauseous taste. On being heated it fuses with the loss of water, and at length blackens, giving off the usual empyreumatic products resulting from the igneous decomposition of the acetates; and if the temperature be very elevated, the oxide of zinc will be likewise reduced.

Acetate of zinc is soluble in three parts of cold and in half a part of boiling water; in thirty parts of alcohol of eighty per cent. at the normal temperature, and in one part at the boiling point. The solutions have an acid reaction.

Uses.—Physiologically considered, the acetate of zinc is reputed to have the same properties as the sulphate, but some French writers deny that it has a poisonous effect even when administered in large doses. The salt is used by dyers as a mordant.

ZINC-WHITE.—This pigment, to which considerable attention has been given of late years, is either the anhydrous oxide, the hydrate oxide, or hydrated basic carbonate of zinc. Its whiteness is equal to that of white lead, and not being tarnished like the latter by sulphurous vapors, it has been proposed to introduce it as a substitute for white lead in painting, especially as it affords a more permanent color, is cheaper, and does not involve the great risk and sacrifice of life which, however carefully the preparation of the carbonate of lead may be conducted, is occasioned among the workers engaged in that manufacture. The principal objection to its general adoption is, that the paint compounded with it is less drying than those in which lead constitutes the basis, and also that it does not cover or spread so

perfectly as white lead; or, in the language of the painter, that it does not possess sufficient *body*. With regard to its non-drying qualities, improvements have been suggested which, if acted upon, would, in a great degree, obviate this objection; and as to the want of body, the painter can well afford to spread a thicker layer of the zinc-white, seeing that a given weight of the latter is considerably more bulky than the same quantity of the former, in consequence of the lesser density of zinc, as well as its much lower atomic weight, which is to that of lead in the proportion of thirty-two to one hundred and four.

GUYTON DE MORVEAU was the first to propose the substitution of oxide of zinc for the basic carbonate of lead in painting. LASSAIGNE likewise drew attention to the subject about 1821, and has lately communicated the fact that an oil painting finished at that time with oxide of zinc has hitherto retained its brilliant whiteness. The manufacture of the zinc-white owes much, however, to M. LECLAIRE, who was among the first to establish its manufacture on a large scale for this purpose. More recently several patents have been taken in England for the preparation of the oxide of zinc for the painter's use, and some of these will be referred to further on.

Manufacture.—At first metallic zinc was the material from which the zinc-white was prepared, the simple change effected being merely the dissipation of the metal in the form of vapor. While in this state, and still at a high degree of heat, the introduction of a current of air causes the metallic vapor to ignite, producing oxide of zinc in a finely-divided white powder, which, when collected, forms the substance in question. The arrangement by which this change is effected is shown in Figs. 645 to 646. In Figs. 645 and 646, the retorts from which the zinc is distilled are represented in section and elevation. They are similar to gas retorts, and are depressed cylinders, *a a*, of refractory clay, such as that of which glass pots are made. Their length is about

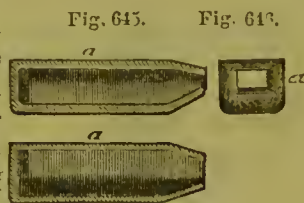
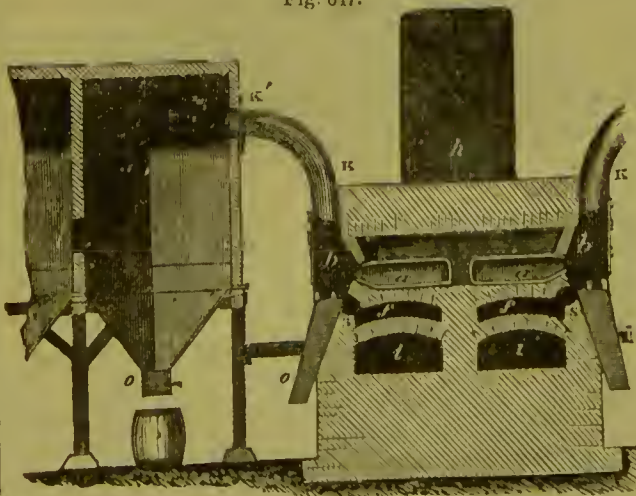


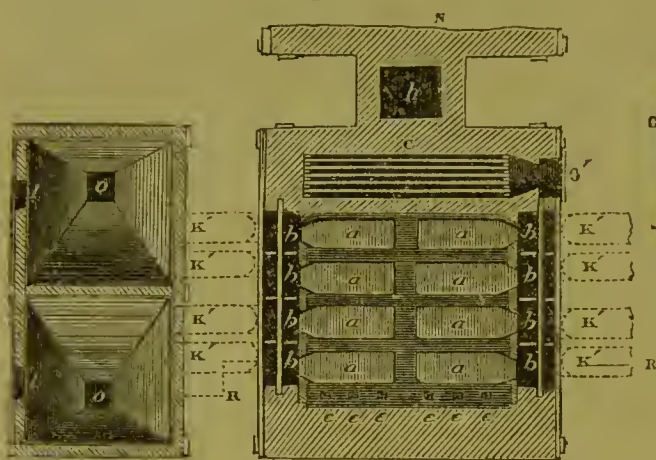
Fig. 647.



twenty-eight inches, their breadth ten inches, and their height about six inches; the walls are two and a

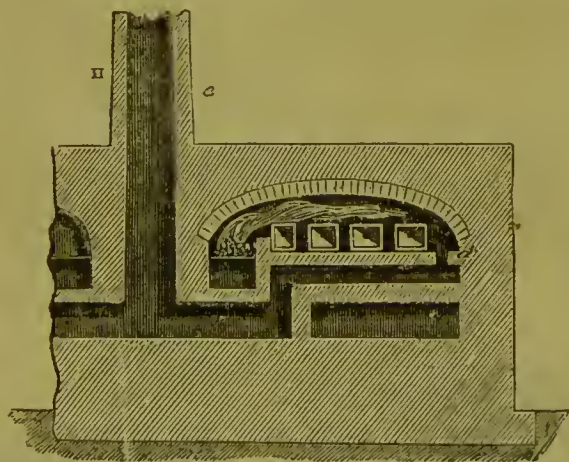
quarter inches in thickness; the aperture, *b*, which serves the double purpose of introducing the pigs of zinc, and allowing the metallic vapors to escape, is four inches in breadth and two in height. Eight or ten of these are placed in a double range, back to back, in a reverberatory, represented in plan and section in Figs. 648, 649,

Fig. 648.



and 650. The fire is at *c*, the heat and flame of which pass over the cylinders and return beneath the floor of the reverberatory by the flue, *c*, *d*, *f*, *g*, *h*, into the chimney, as seen in Fig. 649. When the interior of the furnace and the retorts are observed at a reddish white heat, one or two bars of zinc are introduced into each of the retorts. The metal soon melts and enters into ebullition, the vapor being disengaged by the aperture, *b*, of each retort, where it comes into contact with a

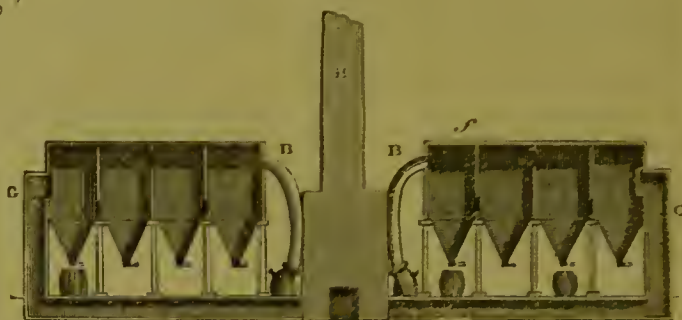
Fig. 649.



current of air heated in the cast-iron pipes, *s s*, to about 570° by the waste caloric of the furnace, and enters into combustion. The metallic oxide so produced is carried along by the current of gas into the pipes, *κ κ*, which surmount the mouth of the retort, and is deposited in the chambers, *L L*, four of which are in connection with each other by apertures alternately at the lower and upper part of their partition walls. The disposition of the condensing chambers and other parts of the apparatus is shown in Figs. 650 and 651. Here *A* indicates the furnace, *B* the pipes leading to the chambers, the last opening in the outer one of which is covered

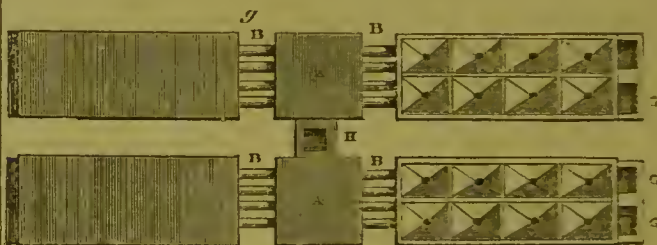
with a fine metallic gauze stretched on an iron sash or framework, for the purpose of intercepting all the particles of the zinc-white, whilst the meshes of the

Fig. 650.



wire affords sufficient space for the egress of the nitrogen and other gases into the flue or passage, *G G*, leading to the chimney, *H*. In this conduit two other screens, similar to that above described, may be fixed, but somewhat finer, to prevent the loss of as little as possible of the powder. After a while the wire gauzes become covered with the powder, but before the meshes are closed they are cleaned and replaced.

Fig. 651



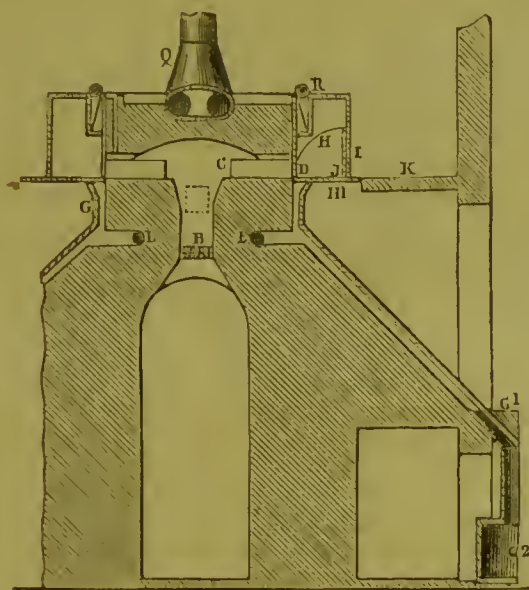
The oxide of zinc thus produced is always of good quality, unless indeed an excess of impurities exists in the metal employed. That which is inferior is always deposited in the first chamber, being impregnated with the oxides of the metallic bodies contained in the zinc, and also with a finely-divided powder of the zinc itself, in consequence of some of its vapor being carried over before it underwent combustion. In consequence of these impregnations, the powder collected from the first chamber should always be screened, and the product devoted to the commoner kinds of painting. It is necessary during the formation of the oxide of zinc, to clear the openings communicating with adjacent chambers, lest the deposition of the powder on the walls should accumulate so as to block up the passage. This is done by means of an iron rod passed through the wall, and commanding the opening. After the conversion of the charge is completed, the oxide of zinc deposited in the chambers is removed simply by placing a barrel beneath the mouth of the hopper-shaped opening in the chamber, and drawing the sliding-plate which is used to secure it while working. The zinc-white is then easily scraped into the receiver, and there reduced by pressure to the least possible volume. It is now ready for the market, or for compounding with the oil as in the manufacture of paint. Three furnaces like those described, each furnished with eight retorts,

work off from twenty-eight to thirty hundredweight of zinc in the twenty-four hours. This quantity ought to produce from thirty-five and a half to thirty-seven hundredweight and a half of zinc-white; but in practice the average yield amounts to only thirty-one and a half to thirty-four hundredweight.

Of late years several improved methods have been devised for the preparation of this substance, the most important of which, in the Editor's judgment, will now be briefly stated.

M. LECLAIRE's mode of operation is indicated in the following description and figures, taken and abridged from *Le Génie Industriel*. Figs. 652, 653, and 654 show

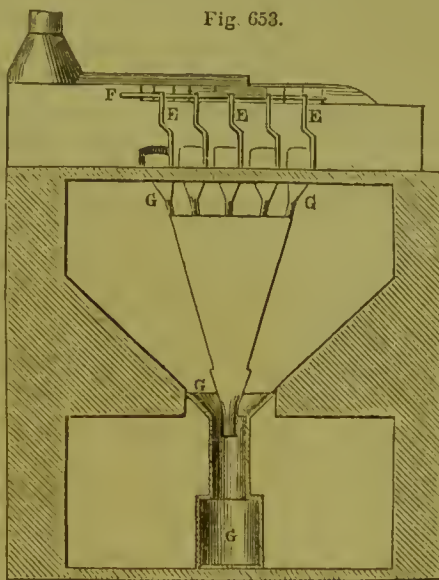
Fig. 652.



the distillatory furnace in longitudinal and transverse vertical sections and in plan. In these figures, A represents the fire-door, B the fire, and C the retorts, which are made of refractory material. Five are generally ranged at either side of the grate, but the number can be varied according to circumstances. The volatilized metallic vapors escape by the orifice, D, of the retort, before which are disposed a series of plates, E, called serapers, attached to a horizontal iron rod, F, by similar pendant ones. By motion communicated by hand or machinery to the horizontal rod, the serapers, E E, are moved backwards and forwards, and coming at each movement against the door of the retort, any oxide which adheres to the aperture is knocked off. The oxide and metallic vapors issuing from the retort are received in small receptacles, G G, which open into an inclined channel that terminates in another funnel-shaped conduit, G¹, and this leads them into the receiver, G². It is evident that the small conduits, G G, receive only such matters as solidify in the mouth of the retort, and which from their density cannot be drawn off to the receivers by the force of the current of gases passing through this arrangement to the chambers wherein the oxide of zinc is collected. A small plate-iron cage or box, H, is fixed over the mouth of each of the retorts in order to isolate them. It rests upon a framework of metal, H¹, fixed into the wall of the furnace, and so constructed that it may be

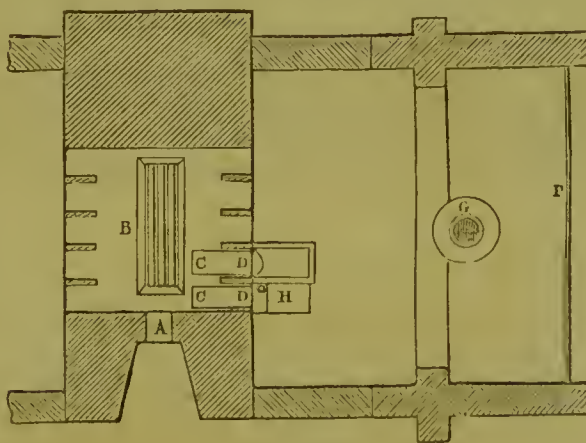
removed at will by means of a crane, or by making it slide or roll on a framework or small railway. The anterior aperture is directed towards the orifice of the

Fig. 653.



retort in such a manner that the products of the distillation empty themselves into it, and the posterior part has a door which may be opened at will. A trap-door, J, is contrived in the suspended plate, K, and which can be raised or lowered at will by an iron-wire rope passing through the posterior plate, I, of the box, II, without opening the door in this part of the latter. Sometimes, instead of lifting the trap-door, it is so formed that it can be drawn backwards when it is necessary to open

Fig. 654.



it. K designates the suspended plate upon which the box or cage is placed; it is isolated in its construction from the chamber of oxidation. Currents of cold air may be directed upon this plate in order to cool it, so as to resist the temperature of the chamber. The hot air, admitted for the combustion of the metal, enters from the pipe, L; it communicates with the passage from the retorts to the receivers, and so drives the oxide of zinc formed into the latter. In the receivers the inventor places cloths for sifting or screening the products, the floor of each being a kind of hopper, or inclined plane, whereby the product gliding over the cloth is separated into its various qualities of fineness, and received at once into separate boxes placed beneath

the sifter. In order to retain the finely-divided particles of zinc-white which arise from the agitation, cloths are suspended at regular distances. These, while they afford a passage to the gases, retain the particles of metallic oxide, and so prevent a loss of material.

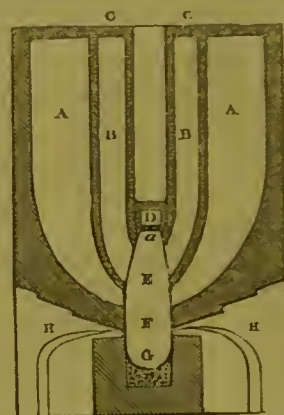
A draught pipe, Q, draws off the air and gases as well as the finely-divided oxide from the oxidising chamber through the whole arrangement. Another pipe, R, placed at the top of each retort, draws into it by a funnel-shaped opening all vapors and powder emitted from the retorts whilst they are being charged, and the draught of which, whenever it is isolated from the oxidising chamber is sufficient to draw the products through a series of chambers not shown in the drawing, having cloth screens as usual to retain the oxide of zinc. The ventilation of both the draught pipes, Q and R, is effected by means of the waste heat of the furnace.

The same inventor combines the principle of the reverberatory furnace in the distillation of zinc for the purpose of making zinc-white. In this arrangement he so disposes the retorts that the flame from the coal fire circulates round them, and then passes into a chamber over the dome inclosing the retort, where pipes may be laid for raising the temperature of the air which is forced into the space surrounding the mouths of the retorts to oxidise the zinc vapors. The oxide so produced is conducted to receiving chambers in a manner somewhat similar to the two methods already described.

ROCHAZ's patent, dated in 1849, describes a construction of furnace suited either to the conversion of metallic zinc, or of ores of this metal, into the oxide. In the first case he uses clay crucibles, and arranges them in three rows in a furnace, supporting them by two intermediate fire-brick walls and by the side walls of the furnace, and so securing the crucibles at the surface that no vapors or smoke from the fire can issue from the chamber beneath them, but must pass off through passages in the bearing walls by small flues into the chimney. A loose slab or clay tile is used as a cover for the vessel wherein the distillation is effected, and the whole is inclosed by a flat roofing of refractory tiles, well cemented and raised a few inches above the crucibles, for the introduction of air from without, for oxidising the metallic vapors. This space leads to a large chamber, in which plates of iron are suspended in a slanting direction, so as to cause the current of vapor, loaded with oxide of zinc, to take a sinuous and zigzag course in passing through it. In addition to these he fixes bands of hemp, or other textile material, at intervals transversely in the chamber, with the view of intercepting the last portions of the zinc-white. Further he contrives that the upper end of these bands shall pass through the walls of the chamber and dip into a trough of water, so as more effectually to condense the zincous vapors in the interior. He directs that the chambers more distant from the furnace be constructed of sailcloth, which affords the advantages of being easily accommodated to space, and of keeping the walls cooled by means of a copious sprinkling of water, applied exteriorly, and which causes the oxide of zinc to deposit more readily. The same patentee

claims a method for preparing the oxides from the ores by a previous roasting, and introducing them, thus prepared, with charcoal or slack, into cylindrical or square clay crucibles, somewhat similar to those employed for the reduction of the metal at Vieille Montagne, but without the condensers, opening into a closed channel in the front, through which a current of air is introduced, and which carries the oxide of zinc, resulting from the combustion of the metal, into a chamber disposed similarly to that described; likewise a blast furnace, represented in Fig. 655, for the same purpose. In this figure the mixture of roasted ore and fuel is introduced into the passages, A A, B B; others are filled with

Fig. 655.



coke or other fuel; all of which are covered with tiles, C C; E, the cavity of the furnace, which is always kept filled with fuel from the passages, B, B, and in which the reduction of the ore is effected by means of the blast introduced through the tuyere pipes, H, H, more especially in the region of F. The slags and residue descend into the cavity, G, whilst the vapors of zinc pass off by the channel or flue, D, into the condensing chamber, as soon as the stopper, a, inclosing the mouth of the chamber, E, is removed. In the latter flue they meet a stream of air that effects their oxidation. The chamber is evidently required to be more extensive in this instance, owing to the gaseous products of the combustion of the fuel being carried along with the oxide of zinc produced in the flue, D; but, excepting this inconvenience, the patentee asserts that no other will result, for all the carbonaceous or sooty products, produced in the region of the blast, are entirely reduced or consumed in passing through the column of incandescent fuel above F, so that only pure gases, which are not calculated to discolor the product, are evolved.

KNOWLYS secured a patent in 1850, in which, among other claims, is a method of preparing the zinc-white from its ores, by dissolving the oxide in sulphuric acid, and, after clarifying the solution by filtration or subsidence, precipitating the metallic oxide with a solution of carbonate of soda. The precipitate, after being washed and collected, is then dried by means of heat and pressure, and the compound so produced is either used in this state or reduced by ignition to the oxide and then compounded into paint in the ordinary way.

PROTHEROE employs an ordinary cylindrical retort, having inlets for the passage of a current of air at the

posterior end, and another for raking out the heavy oxide which forms on the surface of the metal and the walls of the retort, the lighter and finer particles being conveyed by a pipe with the current of air to a condensing chamber, which is divided by partition walls of brick, or other material, into several compartments. In each division he disposes two frames or sashes, on which fine wire gauze is stretched for the purpose of intercepting the particles of powder in their course through the several divisions. Metallic zinc is preferred as the substance to operate upon, and a reverberatory furnace is employed to reduce the metal to vapor. The quantity of heavy oxide skimmed off the surface of the metal and from the walls of the retort, is drawn out by a rake into a passage which conducts it to a receiver in an inclosed chamber beneath the level of the sole of the furnace.

In the method patented by SCOTT, a clay retort of the usual form is used, imbedded in sand, potsherds, or pumicestone, and so placed in the furnace that the products of the combustion pass freely round it. The metallic zinc, which is directed to be used, is introduced through an inclined aperture, which is usually closed by the unmelted portion of the block of zinc. The air which oxidises the vapors of zinc issuing at the top of the retort, is admitted to an intermediate chamber, where both meet, and the product is carried by the current through a passage into a depositing chamber, the roof of which is constructed of zinced iron, and is capable of being converted by a raised ledge, into a shallow cistern, for the purpose of cooling the interior. The bottom of the chamber is divided into a number of funnel mouths, which, by attaching cloth or other material to the narrow part, lead the zinc-white at once into casks placed beneath to receive it.

GEYELIN'S patent, sealed in 1853, is based upon the same principles, only the apparatus is slightly modified, and a jet of steam is employed to effect the rapid oxidation of the metallic vapors as they rise from the retort, and also to aid in producing a certain amount of caloric expended in the operation. The jet of steam is introduced at the farther end of the retort, and passing over the metal, it is decomposed, the oxygen combining with the zinc, and the hydrogen passing off to be consumed in the air channel outside the distillatory apparatus.

TITTERTON prepares the zinc-white from the dross and dregs of the purifying pots of the zinc-smelting establishments by heating them alone, or mixed with a certain quantity of coke or charcoal, according to their composition. He employs two condensing chambers, the first intended for retaining oxide of cadmium, or other impurities, and the second for collecting the light white oxide of zinc. This patentee employs pressure, and a subsequent heating process, with the view of obtaining a denser compound, and therefore better suited for painting.

ZINC-WHITE PAINT.—Like white lead, the oxide of zinc requires to be mixed with an oily vehicle, to be applied in painting. As oxide of zinc does not readily form a saponaceous compound with fats or oils like oxide of lead; the paint which is prepared with it and ordinary linseed oil, does not dry or harden for a long time. This peculiarity was at first one of the principal

drawbacks to the more general use of the zinc instead of the lead paint. Another of its defects is said to be its transparency, owing to which a layer of the zinc-white paint does not exhibit so much *body* or opacity as a similar one of white lead. Both these defects, which can be almost entirely overcome, are more than compensated by the permanency of the oxide of zinc as a pigment under all circumstances, and its comparative innocuousness both in the manufacture and the application; whereas the poisonous qualities of white lead constitute a fundamental objection to it. At first, manufacturers of zinc paint were led to the adoption of the practice of boiling the oil with a large quantity of litharge, for the purpose of causing it to be more siccative; but by this method the color of the paint is rendered liable to tarnish on exposure to sulphurous emanations. Instead of litharge, experiments have led to the choice of salts of zinc, such as the chloride and sulphate, a small per centage of which, on being mixed with the oil or oxide, confers upon the paint the property of readily hardening. The same result is obtained by employing an oil dried by boiling it with about five per cent. of peroxide of manganese, or even magnesia has been recommended, and is said to answer quite as well as the manganese; in either case a paint retaining its white color permanently is obtained.

Manufacturers classify the several qualities of the zinc-white into four kinds, namely, *snow white*, *zinc white*, *stone grey*, and *grey oxide*; the first two are employed where a pure unalterable white color is required; the third is used for a ground color for the walls of houses, iron painting, and the like; and the fourth is peculiarly adapted for the painting of ships and wood-work, and likewise for the ground of more expensive colors on stone or cement. Various shades may be given to paint of which zinc-white constitutes the basis, by grinding up with the oil, used as the vehicle, several metallic and other compounds of an unalterable nature in different proportions. Thus, an orange-yellow is obtained by using kermes—sulphide of antimony; a citron-yellow by employing chromate of zinc; a green by adding a mixture of chromate of zinc and a few per cents. of cobalt blue. In like manner oxides of iron and of manganese, ultramarine, lampblack, *et cetera*, communicate tints to the paint; all of which, owing to the absence of lead, are unaltered by atmospheric influences, sulphide of hydrogen, or other emanations.

Sometimes a very permanent and useful paint is prepared from the natural ores of zinc without subjecting them to any of the manufacturing processes already referred to for preparing the oxide of this metal. This is the case with the zinc-stone of Virginia in the United States, which has an average composition of—

Oxide of zinc,.....	25·00
Carbonate of magnesia,.....	11·21
Alumina,.....	17·00
Silica,.....	28·00

This mineral constitutes a solid rock on the surface of the ground, and when pulverized and mixed with oil in proper proportions, forms on the surface to which it is applied a hard closely-adhering stone coating, impervious to water or fire. Its ordinary tint varies from a

light drab to dark brown. This paint is capable of receiving a high polish.

Oxide of zinc, or zinc-white, besides its application in painting, is valuable for paper-staining, card-enamelling, the bleaching of lace, the glazing of pottery and porcelain ware; and the lighter white portions are used for producing the down on artificial feathers.

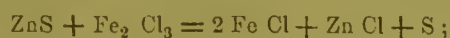
Analysis and Testing of Minerals and Compounds of Zinc.—A short summary of the method followed in the assaying of zinc ores has already been laid before the reader. It is almost needless to state that in consequence of the numerous sources of error almost inseparably connected with it, the process so described leads to no very accurate results. Hence in all cases where great precision is required, the liquid process must be adopted. Considerable difficulties are encountered in the analysis of zinc ores, and the compounds of this metal with others with which it is alloyed, in many valuable mixtures used in the arts—arising from the fact that sulphide of hydrogen does not separate members of the fifth and sixth group of bases, namely, mercury, silver, copper, cadmium, arsenic, *et cetera*, from zinc in acid solutions, as was for some time supposed; nor does potassa or ammonia, on the other hand, serve to isolate it from iron, nickel, and other members of the fourth group. These considerations have led to several processes for removing the cause of error, and conducting to more accurate determinations. As regards the action of sulphide of hydrogen, most of the analytical manuals to which the chemical student has access give details which are highly erroneous, and which, at best, serve only for qualitative rather than accurate quantitative determinations; for, in direct contradiction to what is commonly taught, sulphide of hydrogen does precipitate considerable portions of zinc in the form of sulphide from highly acid solutions. This fact was a few years ago very conclusively decided by Mr. C. CALVERT, whose research shows that the above agent cannot be employed in the manner detailed in the manuals to separate copper and other metals of its class from zinc. Again, potassa, which was for a long time supposed to be capable of parting zinc from iron, nickel, cobalt, and manganese, by dissolving the zinc in its excess, leaving the others permanently precipitated as sesqui- and protoxides, is now known to do so only partially; so that under almost every circumstance in which the precipitation is effected, more or less oxide of zinc is found in the separated oxides. Without going, therefore, into long details of the several processes recommended, the most trustworthy, and, at the same time, most expeditious method for the analysis of zinc ores and alloys will here be given.

The ore or alloy should be dissolved in nitric acid, and evaporated to dryness at a moderate heat, exercising the usual amount of care in the operation. If the subject be an alloy into which tin or antimony may have entered, these metals will be converted into insoluble binoxide in the case of tin, and into antimonious acid in case of antimony, particularly if the assay be treated with some fuming nitric acid, as it becomes nearly evaporated. After thorough desiccation the mass is treated with boiling water, filtered

and washed; the binoxide of tin or antimonious acid dried, burned, and weighed with due precaution, and the filtrate with the washings containing copper, cadmium, or other substances with the zinc, as the case may be, treated further. According to FLAJOLLET, the best process is to slightly acidify with hydrochloric acid, and boil the solution, and add hyposulphite of soda in excess to it whilst hot; sulphides of copper, cadmium, *et cetera*, are precipitated entirely free from zinc, by the decomposition of the hyposulphite. After thorough washing, the precipitated sulphides may be dissolved in acid, and the quantity of copper is determined by the processes already detailed under *Copper*; or if cadmium be present the solution may be treated with carbonate of ammonia in excess, and the vessel left exposed for some time, when carbonate of cadmium falls to the bottom, and the copper remains in the solution, to which it gives a deep violet or blue color. After the carbonate of cadmium is filtered off, washed with a solution of carbonate of ammonia and dried, it may be burned and weighed as oxide. The copper may be estimated with a standard solution of cyanide, or of monosulphide of potassium in the usual volumetric way. The zinc, iron, and nickel, with other matters capable of being separated by the reagent, may be thrown down from the solution with protosulphide of ammonium, the precipitate collected, washed, and dried at 212° till it ceases to lose weight; its entire weight is then noted, and the chief part introduced into a German glass tube on a platinum mattress or boat, where it may be heated to redness, whilst a current of sulphide of hydrogen is passed through the apparatus. When the heat has been sustained for a quarter of an hour, the lamp is removed, but the current of gas is still maintained till the tube and its contents are cooled. The platinum boat is then removed, and its contents emptied into a beaker, and treated with dilute hydrochloric acid, containing one part of strong acid in ten or twelve parts of water; sulphide of zinc is dissolved while the sulphides of cobalt, nickel, and iron remain intact. The quantity of the latter may be determined according to the processes which have been given respectively under *Cobalt*, *Iron*, and *Nickel*, and the zinc in the solution may be estimated by bringing the liquid to a boiling heat, and adding sparingly a solution of carbonate of soda, as long as a precipitate is formed, boiling the menstruum for some time to expel all carbonic acid, and then collecting the basic carbonate of zinc on a filter, washing with hot water, drying, igniting, and weighing the residue. During the ignition all the carbonic acid is expelled from the basic carbonate, so that only oxide of zinc remains, from the weight of which that of the metal may be calculated, since 40.0 parts of it contain 32.0 of zinc.

The oxide of zinc contained in ores of this metal may be determined by heating a weighed portion of them, finely ground, to redness for some time, and then treating the powder with a solution of carbonate of ammonia as long as anything is dissolved; the filtered liquid is next evaporated to dryness, and the residue heated to redness and weighed; this weight indicates the amount of oxide of zinc existing as oxide or carbonate in the ore. SCHWARZ, instead of evaporating

the ammoniacal solution of zinc, as in the foregoing, precipitates the metal as sulphide, either by passing sulphide of hydrogen through the liquid, or adding sulphide of ammonium to it. The sulphide of zinc is collected and washed with water, mixed with a little ammonia, and then introduced with the filter into a wide-mouthed flask, where it is treated with an acid solution of sesquichloride of iron, and slightly heated. Decomposition of the sulphide of zinc takes place in this case, and a reduction of a proportionate quantity of the iron salt to the state of protosalt, as explained by the formula—



that is, for every equivalent of sulphide of zinc one of the sesquichloride of iron is reduced to the state of protochloride, while sulphur is separated from the former, and chlorine from the iron salt assimilated. The liquid, as soon as it becomes clear by the deposition of the sulphur, is filtered off, and the quantity of iron in the state of protoxide estimated volumetrically by means of standard solutions of permanganate or of bichromate of potassa, and the amount of zinc deduced therefrom, since 56 parts of iron will represent 32.0 of zinc.

In the analysis of brasses, PELOUZE's volumetrical method may likewise be resorted to; and, according to CALVERT, with perfect accuracy. The brass is treated with an acid till perfect solution takes place, ammonia is added in excess, and a standard solution of monosulphide of potassium introduced from a burette, whilst a black precipitate forms in the liquid, and until a white one begins to appear. The quantity of copper being found from the volume of liquid used in the precipitation, that of the zinc may be taken as the difference.

Zinc is separated from nickel in many ways. If the alloy containing the two metals be dissolved in sulphuric acid, and the sulphates so produced be treated with acetate of baryta, a sulphate of baryta, with the corresponding acetates of nickel and zinc, will

be produced, with a little free acetic acid in proportion to the quantity of uncombined sulphuric acid which existed in the solution. Sulphide of hydrogen passed through this mixture, throws down the zinc as sulphide, leaving the nickel in solution. The precipitated sulphide of zinc and sulphate of baryta are filtered and washed, then treated with dilute nitric acid to dissolve the sulphide of zinc, and after removing this by filtration and washing from the insoluble baryta compound, the oxide is thrown down as a basic carbonate by treatment with a solution of carbonate of soda at a boiling temperature, then filtered, washed, and estimated as oxide, in the manner already detailed. The nickel can be thrown down as oxide, after expelling the sulphide of hydrogen with caustic soda or potassa, and its weight estimated in the usual way. WÖHLER separates the two metals by adding an excess of potassa to the solution containing them, then a sufficient quantity of hydrocyanic acid to dissolve the precipitate so formed. Double cyanides of the metals with potassium are thus produced, and which behave differently with protosulphide of potassium, the zinc salt only being decomposed by this reagent. By treating the solution, therefore, with protosulphide of potassium, sulphide of zinc separates completely, and may be removed and estimated in the usual way. The filtrate and washings should be evaporated to dryness with strong nitric acid to destroy the cyanogen compound, and the nickel determined by precipitating it with potassa or soda as already indicated.

STATISTICS.—Zinc was not an article of commerce previous to 1822, when it was imported in moderately large quantities, but only to be exported for the most part to India. The applications of the metal in the industry of the nation became gradually extended, till at present the home consumption averages about twenty thousand tons annually. The following table exhibits the imports and exports of the metal from 1823 to 1851; since that period the home consumption has been greatly on the increase, whilst the export remains about the same:—

Years.	Imports.	Exports to India.	Total Exports.	Home used.	Stock in January.	Highest and lowest prices.
1823	5400	4536	4700	—	970	£22 to £23.
1824	9199	7185	8068	24	1140	£21 to £23.
1825	5556	4835	6112	171	413	£22 10s. to £41 10s.
1826	4839	7371	8330	22	924	£28 to £15 10s.
1827	5999	5535	6929	290	1262	£16 10s. to £14.
1828	4566	4806	4943	536	2417	£14 10s. to £11 10s.
1829	4230	3505	3964	684	2012	£12 to £9 7s. 6d.
1830	4422	3385	3479	843	1750	£9 10s. to £11.
1831	3821	2896	3134	911	1512	£11 5s. to £9 5s.
1832	3140	2044	2995	1093	1490	£10 10s. to £11.
1833	2800	1225	1883	1355	1020	£10 10s. to £12.
1834	2100	882	1419	1756	710	£12 to £11 10s.
1835	6500	2197	3943	2205	1350	£15 to £17.
1836	8600	1490	6269	2184	3140	£16 10s., £23 10s., and £19 10s.
1837	4380	1811	3200	2335	2750	£18 10s., £12, and £15.
1838	6265	528	1858	3596	2553	£15 10s. to £20.
1839	8910	1538	3391	4560	3650	£18 5s. to £21 15s.
1840	4965	2637	4091	4181	1536	£20 to £23 10s.
1841	6509	990	1406	3665	2111	£23 10s. to £40.
1842	5500	1581	1900	2641	2800	£36 to £24.
1843	10,173	3459	6445	4125	3750	£23 to £22.
1844	10,393	5826	5925	5388	4021	£22 5s. to £22 10s.
1845	12,903	2969	3084	7459	3296	£22 5s. to £22 15s.
1846	11,431	4875	4967	8450	6800	£22 to £19 10s.
1847	12,729	3301	3631	11,794	2250	£22 to £19 10s.
1848	13,525	2831	3773	9344	2000	£19 15s., £13, and £15.
1849	15,915	3927	5397	8726	2020	£15 to £16 5s.
1850	18,626	3121	4537	11,262	4000	£16 10s., £17 10s., £15, £16 10s.
1851	—	—	—	—	6827	£16 5s. to £15, May 1.

The duty on imported zinc from 1823 to 1825 was twenty-eight pounds ten shillings per ton; this was reduced in 1826 to fourteen pounds; in 1827 to twelve; in 1828 to 1832 to ten, and in 1833 to 1842 to two pounds per ton. The duty levied in 1843 and 1844 was one shilling per ton, and since then all tax upon the imported metal was abolished. The average annual production from 1842 to 1848 was thirty-two thousand five hundred tons, of which—

Silesia made sixty-five per cent.,	or	21,000 tons.
Belgium made twenty	" or	6,500 tons.
Poland made eight	" or	4,000 tons.
Cracow made four	" or	
England made three	" or	1,000 tons.

Total,..... 32,500 tons.

The smelting of zinc declined in England from 1850 till within the last few years that it has been a little more spirited in the several localities mentioned in the commencement of this article; during the same period the Continental establishments, more especially those of Belgium, have greatly enlarged their production. The quantity of zinc produced in the latter country in 1858 was twenty-five thousand six hundred and seventy tons.

The following represents the quantity of zinc smelted in the Prussian States from 1837 to 1848, inclusive:—

1837, .. 21,546,600 lbs.	1843, .. 36,947,200 lbs.
1838, .. 20,983,200 lbs.	1844, .. 41,314,100 lbs.
1839, .. 21,636,600 lbs.	1845, .. 43,861,200 lbs.
1840, .. 20,879,800 lbs.	1846, .. 43,961,000 lbs.
1841, .. 19,977,900 lbs.	1847, .. 44,221,800 lbs.
1842, .. 27,612,600 lbs.	1848, .. 39,873,600 lbs.

Of this quantity there were produced in the upper district:—

	1846.	1848.
In Silesia,.....	35,538,200 lbs.	36,193,100 lbs.
In Westphalia,	189,900 lbs.	75,000 lbs.
In Rhenish Prussia,..	5,322,900 lbs.	3,695,500 lbs.

In France the quantity entered annually for home consumption to about 1848, amounted to eighteen or twenty thousand tons. Estimating the present consumption of that country at thirty thousand tons, that of England at twenty thousand tons, the other Continental nations and America at twenty-five thousand tons, the gross production would appear to average at present from seventy to seventy-five thousand tons annually, a quantity which approximates to the present yield of the several smelting works in operation.

SUPPLEMENTARY MATTER,

BY

PROFESSOR HORSFORD OF AMERICA.

ACETIC ACID.—Insert at foot of column 1, page 3, Vol. I—The oxidation of the glycerin in fats also appears to be a source of acetic acid. By melting rancid Chinese vegetal tallow—palmitate and oleate of glycerin—in a flask, a strong smell of acetic acid is observed. REDTENBACHER found that an aqueous solution of glycerin is decomposed by the presence of ferments, and yields acetic and metacetic acids. By doubling the formula $C_6 H_8 O_6$ of glycerin, and subtracting 4 H, one obtains $C_{12} H_{12} O_{12}$, that is, three equivalents of the hydrated acetic acid. The oxidation of H_4 by the oxygen of the air, would produce the same result. From this it follows, that the acid reaction of rancid fats and oils, is for the greater part produced by the presence of acetic acid formed by the slow combustion of glycerin.—H.

Insert at foot of column 1, page 16.—A very neat apparatus for making small quantities of vinegar from alcohol, constructed by Dr. SPITALER, has been used in Germany for several years. It consists of a cylinder of glass, ten inches high and eight inches wide, filled up with coarsely-powdered charcoal. A glass cover, with a moderate aperture for the admission of air, closes the top of the cylinder, while a small cock is adapted near the bottom for the removal of the fluid. The apparatus must be kept at a temperature between 63° — 77° . Every evening six ounces of a mixture of one quart of alcohol, specific gravity 0.859, and eleven quarts water, are poured slowly and in a fine stream evenly over the charcoal, after which the cover is laid on. The following morning the corresponding quantity of vinegar may be drawn from the cock.—H.

Insert at foot of column 2, page 16.—It may here be interesting to mention an indirect mode of producing vinegar from wood. During the last few years, especially during the crisis caused by the ravages of the potato disease, serious experiments on a large scale have been instituted, with a view to substitute saw-dust and woody fibre in general for potatoes in the distillation of spirit. Many years ago, BRACNOT found that saw-dust, cotton and flax fibres, *et cetera*, are converted into sugar by concentrated sulphuric acid. The sugar thus obtained is fermented in the usual manner, and the alcohol generated may be easily converted into acetic acid by any of the processes mentioned in the text. The cheapness of sulphuric acid, and the universal command of woody fibre, open a promising future to the new and ingenious process.—H.

Insert after PYROXYLIC SPIRIT or WOOD NAPHTHA,

page 25, column 2.—It may be well to remind the American readers, that the high duty on alcohol in England, renders the extraction of the pyroxylic spirit from wood a matter of great importance to the chemist. It is usual in England to burn wood spirit in lamps, and to use it generally as a substitute for alcohol, whenever its empyreumatic flavor is not objectionable, as tolerably pure wood spirit can be obtained cheaper than alcohol.

At page 27, middle of column 2, the reader is directed to use either *sulphuric* or *hydrochloric* acid for the purification of wood vinegar. It is far preferable to use hydrochloric acid for decomposing the lime-salt. Sulphuric acid forms with the lime gypsum, which converts the fluid to be distilled into a paste which it is very unpleasant to distil, as it boils irregularly and sometimes with explosions.—H.

The chloride of barium vinegar-test, mentioned at page 34, column 2, may perhaps be objected to, as calculated to mislead those unacquainted with chemical manipulations. In view of this, BÖTTGER has recommended a concentrated solution of chloride of calcium, for detecting the adulteration of acetic acid by sulphuric acid. He found that all kinds of vinegars, whether prepared from wine, alcohol, fruit, or beer, notwithstanding the small amount of sulphates which they contain, are perfectly indifferent to a concentrated solution of chloride of calcium. By adding to two drachms of vinegar a piece of crystallized chloride of calcium of the size of a small nut, and heating the whole to the boiling point, a precipitate of gypsum will fall down on cooling, if the *liquor contains only one-thousandth part of sulphuric acid*.—H.

In connection with the mordant made by decomposing alum by acetate of lead—see page 37, column 1—it may be stated that the preparation of acetate of alumina by double decomposition of sugar of lead and sulphate of alumina, gives rise to immense quantities of sulphate of lead, which is in many localities treated as a worthless refuse. By digesting it with a strong solution of carbonate of soda, it is converted into an inferior kind of white lead, which might be profitably disposed of, or else dissolved in acids for the preparation of lead salts.—H.

At page 41, foot of column 2, it is stated that the vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor. It may be added, however, that an interesting formation of this compound was observed in a sour

and decomposed sugar-cane which had been sent from Andalusia to Paris. On splitting the cane open, a very strong smell of acetic acid and acetate of oxide of ethyle was perceptible. It is obvious that the presence of this compound, under the given circumstances, must be explained by the contemporaneous formation of acetic acid and alcohol from the sugar, both of which combine in the nascent state to form acetic ether.—II.

At page 42, column 1, it is stated that for commercial purposes, the protoacetate of iron is manufactured by introducing the materials into a large cast-iron boiler. By employing a copper kettle or boiler, the solution of the iron is effected more rapidly by galvanic action. As long as there is any iron left undissolved in the kettle, the copper will not be acted upon by the acid. A few drops of a solution of bichloride of platinum, added to six or eight ounces of concentrated hydrochloric acid used for dissolving tin, will induce a very violent action, and the tin will dissolve, requiring but little aid by heat. The same takes place when bichloride of platinum is added to the acetic acid for preparing protoacetate of iron.—II.

Insert, in connection with white acetate of lead, page 44, column 1.—It is a well-known fact among phytochemists, that sulphide of lead has a great affinity for coloring matters. Based on this observation, a German chemist proposed to decolor a colored solution of acetate of lead, by the addition of a small quantity of sulphide of potassium or sulphide of calcium. After boiling and filtering, the menstruum is clear and without hue.

ALCOHOL.—At page 50, top of column 1, it is stated that alcohol is never produced except by the vinous or alcoholic fermentation of particular substances. There is one exception to this rule. Pure olefant gas is absorbed by agitation with concentrated sulphuric acid, with formation of sulphovinic acid; and by diluting the latter compound with water, and distilling the fluid, alcohol is obtained. This fact was discovered twenty-seven years ago by HENRY FLENNEL, though, singular to say, the discovery has lately been claimed by BERTHELOT.—H.

Insert at foot of column 1, page 107.—*Dunder* fulfils two important offices in the distillation of rum. In the first place, the large quantity of acetic acid contained in it, and formed at the expense of alcohol during fermentation of the wash, serves to decompose the sugarate of lime, contained in the generality of West India molasses in considerable quantities. It is for this reason that *dunder* increases the yield of rum. Sugarate of lime does not ferment, and when present in considerable quantity, actually opposes the fermentation of the wash; so that without *dunder*, fermentation would proceed so sluggishly that most of the alcohol would be converted into vinegar. This occurrence might be avoided by adding the diluted molasses containing sugarate of lime, to its own bulk of strongly fermenting wash. The carbonic acid of the fermenting liquor would then perform the office of the acetic acid of the *dunder*, by precipitating the lime as carbonate of lime and liberating the sugar. The American Editor disproved the idea that *dunder* is connected with the fine flavor of rum, by two experiments. In

one trial, molasses—from which all the lime was precipitated by sulphurous acid—and water only were used. The resulting rum was a very fine-flavored spirit, and the yield was perceptibly greater than from molasses not thus treated, though from similar cane. Another trial was made by partially filling the rectifying vessel, or retorts, as they are called in Jamaica—they are like the wash-heater, as prepared in, Fig 78, and connected with the still in the same manner—with *dunder*, with a view to increase the flavor of the rum, as might be expected if the flavor proceeded from that source. The rum, however, thus obtained had the disagreeable flavor of the *dunder* totally different from that of *Old Jamaica*. The flavor of the rum appears to depend entirely on the presence of a fusel-oil, the formation of which is immediately dependent on the proportion of the surface of the wash exposed to the air during fermentation, to its entire volume. It is well known that two contiguous sugar plantations will produce very different qualities of rum, though operating in the same identical way. But it has been observed that in such cases the size and the exposed surface of their fermenting vats were different, or if not, the stills were of different capacity. The protracted boiling of the wash in very large and deep stills, injures the flavor by increasing the empyreumatic products. From the above observation it would follow, that the origin of the genuine flavor is intimately connected with the more or less complete oxidation of the molasses ferment induced by the greater or smaller surface of the wash—compared with the bulk—exposed to the air. Large cubical cisterns, holding one thousand and more gallons, yield an inferior rum, as compared with smaller vats having a larger exposed surface. Similar observations made by LIEBIG with regard to Rhenish wine appear to confirm this opinion.

The second office fulfilled by *dunder*—an office of some importance for the more rapid development of fermentation—is by its richness in ferment. The colonial distiller does not employ any yeast for inducing fermentation of his wash; he is consequently obliged to work upon more dilute solutions of molasses and skimmings—collectively called *sweets*—than are used by his continental competitors. Any, even the slightest source of ferment, must therefore be welcome for his purpose. *Dunder* is such a source. Ferments, it is well known, are destroyed by boiling-heat of water, and recent *dunder* is in that respect perfectly inert; but by exposure to air in shallow tanks, an oxidation and regeneration of the *killed* ferment takes place, and it is to this circumstance that a part of the favorable action of *dunder* must be ascribed.

Without the assistance of *dunder* a more rapid fermentation of the wash may be obtained by converting the cane-sugar contained in molasses into grape-sugar, by treatment with a small quantity of acid, which is subsequently neutralized. It has been stated that less ferment is required for converting grape-sugar into alcohol than cane-sugar, a fact which will render it less miraculous to hear that some plantations manufacture a superior rum while their sugar is nearly as dark as coal-tar. Molasses from such sugar contain chiefly grape-sugar. Allusion has already been made to the

fine flavor of rum made from molasses which were obtained by boiling sugar with an excess of bisulphite of lime.

Cleanliness in the operation of the distilling is a standard admonition of the theoretical world, woefully disregarded by the practical. In fact, it appears that a premium is offered to malpractice in this instance, as many of the most detestable colonial distilleries turn out very creditable produce. Whether the exception proves the rule in this case, must be left undecided. However, if cleanliness is not absolutely required for improving the flavor of the spirit, it would be a charity to the still-house bookkeeper, who is condemned to pass part of his lifetime in these disgusting dungeons.—H.

Page 117, column 2, *Alcoholometry*.—To the analytical chemist it happens sometimes that only small quantities of the alcoholic fluids are at his command. In such cases it is almost impossible to obtain a correct result, by determining the specific gravity of the few drops of alcohol obtained by distillation. It is safer to subject the alcohol obtained to an organic analysis by combustion with oxide of copper, and calculate the quantity of absolute alcohol from the resulting carbonic acid and water. This is of course only applicable when the alcohol does not contain other volatile bodies, like ethereal oils, *et cetera*.

ARSENIC.—At the top of column 2, page 215, Vol. I., insert—In the presence of oxide of iron, minute quantities of arsenic cannot be detected by the blow-pipe. In that case, the oxide of iron must be treated with a boiling solution of potash, which is afterwards neutralized by sulphuric acid, and tested in MARSH'S apparatus.

In same page and column the reader is directed to drop a few fragments of pure zinc into MARSH'S tube-apparatus. It deserves to be remarked, however, that pure zinc, especially when in large pieces, frequently dissolves so slowly in dilute sulphuric acid, that it is impossible to obtain a steady hydrogen flame. The addition of a drop of bichloride of platinum, or of a small quantity of platinum black, will remedy this difficulty. If the fluid to be tested contains any considerable quantity of arsenic acid, this alone is sufficient to produce a violent reaction of the acid on the zinc.—H.

BALSAM.—Vol. I., column 1, page 223.—*Canada Balsam*.—This balsam is mostly used by optical instrument-makers for cementing together the different parts of achromatic lenses, NICHOL'S prisms, *et cetera*. It may be here added that Japan varnish is a balsam derived from *Rhus vernix*, and serves to impart a brilliant lustre to metallic and other objects, hence denominated *japanned articles*.

BEER.—In connection with the analysis of beer, pages 281–284, the following may be given:—

ANALYSIS OF VARIOUS KINDS OF CELEBRATED BEER.

	Water in 100	Extractive matter	Alcohol	Carbonic acid	Analyst.
Barclay's ale, . . .	86.93	6.02	6.90	0.15	Raiser.
Burton ale,	79.62	14.50	5.88	0.04	Hoffmann.
Pale ale,	89.85	4.50	5.65	0.07	"
Barclay's porter, .	88.74	5.98	6.10	0.18	Raiser.
London porter, . .	86.28	6.80	6.91	—	Balling.
Bavarian ale, . . .	90.95	4.70	4.34	—	"
London ale,	76.03	15.88	8.08	—	"

BENZOL.—Insert at foot of column 1, page 286, Vol. I.—The rectified volatile oil from coal-tar, distilling between 212°–320°, and consisting mostly of benzol, toluol, and cumol, has been strongly recommended for oil paint in the place of oil of turpentine. It has the advantage of evaporating rapidly, whereby apartments painted with oil paint are rendered much sooner inhabitable.

A curious and interesting application has been made of benzol by the well-known photographer, M. DE ST. VICTOR, based upon the property of this fluid, to be lighter than water and insoluble in it, and to be kindled with the greatest facility by a small flame in contact with air even at low temperatures. He found that benzol, to which have been added a few pieces of potassium or phosphide of calcium, readily inflames when thrown on water. An experiment was made on the Seine in Paris, in which three hundred grammes of benzol were inclosed in a glass-bottle, with half a gramme of potassium. The bottle was floated down the river, and suddenly broken. The potassium ignited and set fire to the benzol which burned with an immense flame, which, though smoky, had great intensity, and lasted fully a minute in spite of a strong breeze.

A repetition of this experiment in the fountain of the garden of the Palais Royal gave the same result. In spite of a heavy rain, the flame lasted over a minute.

M. DE ST. VICTOR proposes a mixture of benzol with sulphide of carbon in which phosphorus has been dissolved, as a close imitation of the famous liquid Greek fire.—H.

BISMUTH.—Insert at foot of column 1, page 288.—An alloy for galvanoplastic moulds is prepared by fusing together eight parts of bismuth, eight parts lead, three parts tin. This mixture melts at 225°. For preparing the mould, the alloy is fused and poured into a paste-board boat of about one quarter inch depth; it is then stirred with a heated iron-wire until its surface is perfectly even and bright. As soon as it has acquired a pasty consistence, the medal to be moulded is slightly heated, and immediately pressed on the alloy, and kept under pressure until cool.—Böttger.

BLEACHING.—Insert at foot of column 1, page 315, Vol. I.—Mr. L. BENNER, chemist of KÖCHLIN'S print-works at Darnetal, near Rouen, has lately recommended the use of sugarate of lime—sugar-lime—in place of caustic lime for bleaching of cotton fabrics. He describes his process as follows:—For one scouring operation, two hundred pieces of fourteen pounds each are worked upon, and the operation is performed in large kiers, heated on the open fire, and under a pressure of about twenty-two pounds to the inch. As soon as the pieces are singed, they are passed through a washing-machine—similar in principle to ROBINSON'S—in order to moisten them sufficiently to prevent any danger of combustion. After this they are wound by a mechanism into a tub in which they are spread in largo folds. During the latter operation a milk of lime, containing forty pounds burnt lime, runs on the pieces in such proportion that the forty pounds of lime will be used up by the two hundred pieces. From this lining tub the pieces are mechanically transferred to the bucking kier, in which

they are arranged in separate layers. After covering and fixing the fabrics by wooden cross-bars, as much water is added as will cover the pieces to the height of twelve inches, after which the sugar-lime is added. The latter is prepared by mixing in a tub thirty pounds burnt lime with seventy-two pounds boiling water; after slaking, thirty-six pounds more of hot water are added to dilute the lime-paste. To this milk of lime are added fifteen pounds of molasses, previously diluted with thirty-six pounds of hot water. The whole is well stirred and thrown into the bucking kier, whereupon the cover is fastened, and the charge kept boiling for eight hours. The fire must, however, be increased very gradually, so that the operation is finished in about ten hours.

This operation ended, the pieces are taken out, passed twice through the washing-machine, and brought back again into the bucking kier. The pieces are folded up as before, covered with twelve inches of water, which is mixed with the sugar-lime prepared from thirty pounds of burnt lime and ten pounds of molasses. The charge is again boiled during eight hours; the pieces are then removed, passed twice through the washing-machine, and steeped in hydrochloric acid of specific gravity $1.010 = 2^\circ$ Twaddell during four hours. They then undergo two washings—are brought back to the bucking kier a third time to be finished for bleaching by a single soda-ley.

The sugar-lime being readily soluble in water, and acting in all respects like free lime, has, of course, the great advantage of intimate contact with all the particles of grease and resinous substances which are fixed on the fibre; while the caustic lime, in consequence of its restricted solubility, especially in boiling water, is less complete in its saponifying functions.

The bleaching process is carried out as follows:—After packing the pieces in the bucking kier, and covering them with twelve inches of water, a solution of sixty pounds of soda-crystals is added, the cover of the kier fastened, and the charge boiled for three hours. The fire is then withdrawn, the steam allowed to escape, and the cover removed. The soda liquor is drawn off and replaced by cold water, to which a resin-soap, prepared of one hundred pounds of soda ash and one hundred pounds of resin, is added. The cover is replaced, and the charge boiled for twelve hours, after which the soap-ley is withdrawn, the kier filled up with cold water as before, a solution of sixty pounds of soda crystals added, and the charge again boiled for three hours. The pieces are now removed to undergo the washing process twice, before being wound into the bleaching solution of chloroxide of calcium, where they remain a few hours; hence they pass through water, then receive a scouring in weak hydrochloric acid, and pass twice through the washing-machine.

Pieces which have not been treated with solution of chloroxide of calcium, are equally as well adapted for dyeing purposes; and the treatment with bleaching liquor may therefore be dispensed with for the greater part of the pieces.

The first scouring with soda crystals is intended to remove traces of acid, and most of the resinous matter, to prepare and aid the action of the resin-soap.

The second boiling with soda crystals is to remove

the remainder of resinous substances, and also to free the fibre from adhering resin-soap.

This method of giving two scourings with sugar-lime offers the great advantage over those methods, where only one scouring with a comparatively strong ley of lime is employed, of weakening the fibre in a less degree.

ANTICHLORINE.—The property of cotton and other woody fibre to condense gases and colors on its surface by a peculiar physical attraction, is well understood. This action, which it has in common with all solid bodies, is so powerful in some instances, that it may even counteract chemical attraction. Cotton and other vegetal fibre which has undergone the bleaching process by chlorine, for instance, has the property of powerfully retaining some chlorine gas. The difficulty of removing this effectually from the bleached fibre is almost insurmountable, requiring a great sacrifice of time, when rapidity is so essential, besides large volumes of water and increased machinery. Now, in order to insure the proper rapidity of the manipulations, either an appreciable amount of chlorine must be left in the bleached fabric or paper-pulp, or else this chlorine must be removed by substances bringing superior chemical affinity into play.

The expedient of only partially removing the chlorine from cotton cloth is certainly in favor of the manufacturer, to the evident disadvantage of the consumer. Chlorine acts gradually on the fibre; it combines with its hydrogen and disorganizes it, renders it brittle, aided by the hydrochloric acid formed. The same is the case with paper-pulp. The action of chlorine left in the bleached pulp is particularly illustrated by the paper manufactured in France soon after the introduction of chloroxide of calcium into the paper-mills. The paper, on running over the hot drying rollers of the machine, becomes brittle; the books printed on it gradually become full of brown spots, and acquire a uniform brownish tint. Every bookseller is acquainted with the inferiority of the modern printing paper in this respect. This deterioration must be entirely ascribed to the action of free chlorine, adhering to the fibre. It is not the paper alone that suffers; the type, too, with which it comes in contact, is affected in proportion to the amount of chlorine left in the paper. It is well to direct the attention of paper-makers and printers to this point, and so furnish them with a ready explanation of the rapid deterioration of the paper and type, and to draw their attention to those chemical agents which may be employed with advantage for counteracting these evils. Agents of this description have been introduced to the public under the general designation of *antichlorine*.

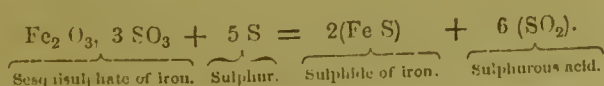
Carbonate of soda or ammonia was first proposed as an antidote for chlorine; but though the latter gas decomposes soda or ammonia in concentrated solutions, the effect in very dilute fluids is very insignificant, and requires the aid of heat. Sulphide of calcium was next introduced; but its property of being decomposed by carbonic acid, with evolution of the fetid sulphide of hydrogen gas, and the black precipitate which it produces with any salt of iron or copper which may be present in the pulp by accident, preclude the use of

this salt. Protochloride of tin—tin salt—and a mixture of protosulphate of iron and salt, have the disadvantage of introducing metallic salts into the pulp, which are about as objectionable as chlorine itself. Hyposulphite of soda is somewhat expensive, and precipitates sulphur when brought in contact with chlorine or hydrochloric acid, the sulphur giving a yellowish tint to the paper. Recently a patent was taken out by ROTH and LEA of Philadelphia, for the use of a solution of sulphite of soda as an antichlorine. Sulphurous acid and its salts are indisputably the most economical, besides being the most efficient chemical compounds for removing free chlorine. Sulphurous acid alone, however, cannot be employed for the purpose in question, on account of being converted by chlorine into sulphuric acid, which has a detrimental action on woody fibre. The sulphite of soda answers, therefore, all practical purposes, as far as its chemical action is concerned; it is, however, still liable to the objection of difficult transportation in its fluid state, in which it must be sold for reasons of economy, entailing additional expense on the consumer for water-tight casks and freight of a valueless substance—water. These considerations, which oppose a more general application of the sulphite of soda, have induced Professor HORSFORD to make the use of the cheap sulphite of lime or *antichloride of lime*, the subject of a patent for England and America.

It may appear on first consideration that neutral sulphite of lime, which is very little soluble in water, could have but little effect on the chlorine combined with the fibre; but the fact that hydrochloric acid dissolves neutral sulphite of lime with formation of soluble bisulphite of lime, will readily explain its action. Now hydrochloric acid is invariably generated whenever chlorine gas acts as a decoloring agent on organic substances.

It is the hydrochloric acid thus generated which dissolves the neutral sulphite of lime. Contact with chlorine converts the sulphite into sulphate of lime, which goes to increase the weight of the paper, and practically saves to the manufacturer nearly or quite the whole cost of the sulphite of lime. The article is prepared by agitating milk of lime by means of revolving paddles in a long close box, with fumes of burning sulphur, until the reaction is neutral or acid. It is then drained and air-dried, and packed in casks for transportation.

In connection with the formula given at page 324, column 2, it deserves to be stated that, instead of taking the protosulphate of iron— FeOSO_3 —for the preparation of sulphurous acid, it is more advantageous to employ the *sesquisulphate of iron*— $\text{Fe}_2\text{O}_3, 3\text{SO}_3$ —which is obtained by *roasting* green vitriol in the air, and then adding to it half as much more sulphuric acid as it already contains, and evaporating the resulting pasty mass to dryness. One hundred and ninety-eight parts of the dry sesquisulphate of iron are now mixed with eighty parts of sulphur, and heated, whereby one hundred and ninety-two parts of dry sulphurous acid gas are obtained:—



while one hundred and ninety-eight parts of the *protosulphate of iron* will only yield one hundred and sixty-nine parts of sulphurous acid.—H.

BLEACHING POWDER.—At page 328, immediately preceding the formula at foot of column 1, it is stated that the chlorine employed in the experiments was prepared by adding hydrochloric acid to chlorate of potassa. But BÖTTGER found that the gas thus obtained contained ClO_3 . It is to be presumed that the mixed gases were passed through sufficient water, and at a rate sufficiently slow to permit the entire absorption of the ClO_3 .—H.

At page 329 a description is given of FRESSENIUS and WILL's method for testing the quality of manganese ore. A modification of this method, more simple, and still equally satisfactory for practical purposes, has been proposed by MOHR. It is executed in the following manner:—Three grammes of the finely-powdered and dried manganese ore are mixed in a small glass flask with a little water, and enough sulphuric acid to render the whole mass perfectly fluid. This flask and a porcelain capsule containing about nine grammes of crystallized oxalic acid, are now placed in one scale of the balance, and brought into equilibrium by a basin of sand or small shot. The oxalic acid is now thrown into the flask, where it immediately begins to reduce the binoxide of manganese under evolution of carbonic acid. To accelerate this decomposition, it is good to give the flask a circular horizontal motion, until the evolution of the carbonic acid has ceased, and the mass from black, which it was, has become light-colored. The empty porcelain capsule and the glass flask are now again placed on the balance, and so much weight placed into the capsule as to restore the equilibrium. The weight required to effect this is equal to the weight of a binoxide of manganese in the ore, because one equivalent of binoxide of manganese = 44, when treated with oxalic and sulphuric acids, cause the evolution of two equivalents of carbonic acid = 44; one part by weight of binoxide of manganese is therefore indicated by one part of carbonic acid.

Now, as three grammes of ore have been employed for the above experiment, it follows that the amount of carbonic acid lost, divided by three, indicates the amount of binoxide of manganese in one gramme of the ore; and by multiplying the latter number with one hundred, the per centage of the binoxide is obtained. The error produced by the loss of water in this method does not signify for most practical purposes, but may be remedied by closing the flask with a cork in which a glass tube filled with dry chloride of calcium is fastened. In this case, however, the carbonic acid contained in the flask when the experiment is finished must be removed by suction.—H.

BONE BLACK.—At page 336, eleventh line of first column, it is stated that solutions of sugar are better deprived of their color when alkaline than when acid. This, however, only applies to an alkalinity of sugar sirup produced by *lime*.

Some interesting reflections are suggested by the remark which follows in the same column with reference to the decoloring power of carbon, and M. Bussy's

experiment, showing that the reaction is strongly influenced by ordinary chemical forces, instead of being purely mechanical. As the whole universe, with all its diversified phenomena, derives its origin from one *primum movens*, and as all the phenomena connected with matter can therefore only be functions of this creative unit, one may, *a priori*, expect that which is actually observed, namely, the gradual transition and intimate connection of varied effects and causes. Where does inorganic nature cease and life commence? Where stops the action of light, and where does heat begin? Why does magnetism induce electricity? Where do the physical forces—cohesion, repulsion, heat, electropolarity, light and contact force, find a landmark which separates them from what are denominated chemical forces? Every effect must have a cause, and every distinct effect a distinct cause; but it is the defect of the human mind to be slow in distinguishing apparent from real differences. Before NEWTON it would have been undoubtedly considered good logic to conclude, that the force which made the apple *fall* was different from that which kept the earth *steady*. Thus it comes that all definitions of isolated systems fail, and undergo continual amputation and restoration with every progress of science—now hobbling on one bandaged leg, now on another—showing that nature abhors, if not the vacuum, at least systems and definitions; and it teaches that there is no gap in its mechanism, no wheel or spring wanting in its clock-work; in fine, there is no interruption in its development from a single cause or *animus* to its utmost complicity, which is observed in the perfection of organic existence. A disruption in the continuity of effects in the economy of nature would be equal to the interruption of an electric wire between two telegraph stations; because in that case the intelligent cause on one station could no more produce an intelligent effect on the other, in consequence of an apparently insignificant accident. The forces as connected with the phenomena of matter, are in the same predicament. There can be no *real* difference in the so-called forces, because such a difference would constitute a *real* gap; it would stamp the force as an individual, producing an individual effect, so that all the infinitely different effects observed must be ascribed to infinitely different forces.

The attraction of coloring matter by charcoal is denominated mechanical, while the attraction of sulphuric acid by baryta is classed with chemical effects. But animal charcoal does not only attract coloring matter; it also decomposes metallic salts, and fixes their base by that same power of retention. Now it is known that chemical combinations and decompositions are produced by differences in intensity of one only chemical attractive force called affinity. It is evident that the same force is inherent in animal charcoal. This view is corroborated by the fact that animal charcoal absorbs different compounds in different but determined quantities. NIERCE has shown that iodine and chlorine gas are condensed by the inked portion of printed paper, while the white portion of the paper does not retain any of the gases. Charcoal absorbs heat and light most readily. It condenses

electricity on its surface, and thereby acts as a non-conductor, the same as glass, which is only an isolator in consequence of its great attraction for electricity. Metallic charcoal loses, with its power of attracting colors and gases, also the power of attracting electricity, which latter now passes through without hindrance, as through other conductors. Ordinary charcoal condenses gases, and frequently causes chemical combinations. This substance, then, shows the gradual development of chemical effects by physical forces. The effect of animal charcoal depends entirely upon its porosity and the extent of its carbonaceous surface, and is directly proportional to it; and it may therefore be presumed that if the surface of charcoal could be indefinitely increased by solution in water, it would produce all the powerful chemical phenomena of cyanogen or ozone.

If one moves on a step further, binocide of tin presents itself, a substance already more pronounced in its chemical character than charcoal. Still it is inclined to combine equally as well with bases as with acids, showing a transition character. Now, if pumice be soaked in a solution of bichloride of tin, and then dipped into a solution of carbonate of soda, the pumice acquires all the properties of animal charcoal. Very porous pumice, finely-divided silica, cotton fibre—all these show signs of chemical power depending on their extent of surface; and it may well be supposed that this chemical power would be more prominent, could they be obtained in the fluid state. Silicic acid, which is as inert as charcoal at the ordinary temperature, drives out the powerful sulphuric acid from its combinations at a temperature nearer its own melting point.

Another phenomenon is also connected with the action of animal charcoal, namely, that of endosmosis. It has been shown, as subsequently stated in the text, that a colored sugar solution containing, besides water, some salts, does not pass unchanged through animal charcoal. Pure water is the first to pass through, then comes water with salts, then sugar, and lastly, the color. From this one concludes that animal charcoal has the greatest affinity for coloring matter, less for sugar solution—because the latter is replaced by the former—still less for salt solution, and least of all for water. Could, therefore, a thin diaphragm be constructed of animal charcoal, one would observe the endosmosis to take place from a salt solution into water, and from a solution of sugar into salt, and from a solution of coloring matter into water, salt, and sugar; that is, of such tinctorial matter as has the greater affinity for animal charcoal. Thus a certain molecular attraction in animal charcoal may produce effects ascribed to a multiplicity of forces, as mechanical force—adhesion, endosmotic force, catalytic force; and chemical force—affinity. Would it not be more rational to consider all these as mere functions of the same molecular tendency the intensity of which alone gives rise to variable effects, the same as is observed in sound, electricity, and light?—H.

CORRENWINDER assumes that the decoloring effect of animal charcoal is correlative to its absorbing power for lime; and on this supposition he bases the following method for determining the commercial value of bone

black:—A solution of sugarate of lime is prepared, containing, say, twenty grammes of lime in one thousand cubic centimetres fluid, which are neutralized by one thousand cubic centimetres of a standard solution of sulphuric acid, so that fifty cubic centimetres of the acid solution indicate one gramme lime.

The samples of the bone black are now rendered of a uniform condition, by passing them separately through the same sieve, after having removed the fine dust by a paper fan. Fifty grammes of each sample are placed each in a glass flask. In each glass flask one hundred cubic centimetres of the solution of sugarate of lime are added to the bone black, and the whole allowed to digest for an hour. After this the fluid of each flask is filtered separately, and fifty cubic centimetres of the filtrate liquor are tested for the amount of lime with the standard solution of sulphuric acid. The more lime there is absorbed by the bone black, the less sulphuric acid will be required to neutralize the filtered liquor; and that liquor which requires least acid for neutralization, must have been in contact with the most valuable sample of bone black, so that the value of the animal charcoal increases directly as the amount of standard acid required for neutralization decreases.—H.

BORACIC ACID.—At page 342, it is stated that boracic acid scarcely reddens vegetal blues, and renders turmeric brown, like an alkali. This reaction affords an easy means of detecting boracic acid in its combinations, by adding to it a little hydrochloric acid; after which dip into the fluid a piece of turmeric paper, and then dry it. If a trace of the acid was present, the paper will have a brown stain after drying.—H.

BREAD.—Insert at foot of column 1, page 377, Vol. I.—The frequent failure of the grain crops, and the scarcity of grain induced by some other accidental causes, has drawn the attention of chemists to the process of bread-baking, either with a view to discover some substitute for wheat flour, or else to find the means for rendering the whole of the nutritive principles of the cereals available for consumption. The latter direction has already furnished valuable results. It is known that the bran separated from flour contains a comparatively large proportion of nitrogenized substance, namely, that constituent of the flour which contributes most to nutrition. Until quite recently the bran was lost to the nutrition of man. Now, however, it has been shown that this nitrogenized substance may be extracted from the bran without much trouble and expense, so as to obtain the whole of its valuable matter. This process, recommended by a number of chemists, was ultimately patented in France by a Mrs. DURUT. The manipulation is carried out in the following manner:—Bran is mixed up with boiling water in a kettle over a moderate fire, so that the mixture has a semifluid consistency. The mixture is now heated carefully until the bran loses its raw smell—not till it is cooked; it is then transferred into bags and pressed. The pressed cake is treated once more in the same manner, mixing it with water, allowing to boil for a short time, and pressing. The fluid obtained by this second operation is used, instead of pure water, for a fresh portion of bran. By the first pressing a sirupy

juice is obtained, completely saturated with gluten, and which is destined to replace the pure water in the process of bread-baking; thus gaining for the bread a large proportion of valuable nutriment entirely lost before. The economy of this process is thus stated:—A bag of flour of the average weight of three hundred and twelve pounds, made into bread with water in the usual manner, yields on an average one hundred and four loaves of four pounds each. A bag of flour of the same weight, made into bread with the extract of bran, yields one hundred and thirty loaves of four pounds each, or a clear gain of twenty-six loaves over the old process. Twenty-five per cent. increase in the yield of bread from the same amount of flour is a fact the importance of which cannot easily be exaggerated.

BROMINE.—The process detailed at pages 393, 394, for the separation of bromine and chlorine, may with advantage be modified in the following manner:—Precipitate the solution containing chlorine and bromine with nitrate of silver; wash, dry, and heat the precipitate to a state of semi-fusion in a weighed porcelain capsule. Weigh the capsule with the silver precipitate, then reduce the latter with the aid of zinc and sulphuric acid in excess. Wash out the reduced silver, ignite, and weigh it. If one supposes the weight of the chloride and bromide of silver to be a , and that of the metallic silver obtained from it by reduction with zinc to be b , and the amount of chlorine to be x , the amount of bromine will be $a-b-x=y$. From this we conclude:—

$$\frac{107.97x}{35.46} + \frac{107.97y}{79.97} = C,$$

from which is deduced:

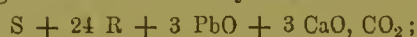
$$x=1.38674C-0.79667a$$

That is, multiply the weight of the reduced silver by 1.38674, and deduct from the result the product obtained by multiplying the weight of the chloride and bromide of silver with 0.79667, and the result will be the amount of chlorine in the mixture. By subtracting the weight of the chlorine plus that of metallic silver from the weight of the chloride and bromide of silver, the amount of bromine is obtained.—H.

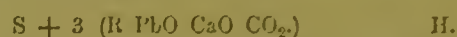
CANDLE.—Read, in connection with the processes described at pages 430, 431:—The operations of saponification of the fat, and decomposition of the lime-soap by sulphuric acid, have been hitherto effected in open vessels, under the ordinary pressure of the atmosphere. An improvement on this plan has been recently proposed by M. DELAPCHIER, of Besançon, who substitutes close vessels in order to saponify the fat. Wash and decompose the lime-soap under a pressure of about twenty-two pounds to the square inch, by which the operations are considerably facilitated, and their duration shortened. The products by this process are said to be superior to those obtained in open vessels, and a considerable economy of fluid is effected. The apparatus consists essentially of a horizontal boiler, with a man-hole and two safety valves at the top. The heat is furnished by a large steam-pipe, running in a depression along the bottom of the boiler. The

pipe is perforated with numerous holes to distribute the heat more uniformly. A horizontal iron shaft, which passes through stuffing boxes in the heads of the boiler, carries an agitator, the transversal ribs of which nearly touch the circumference of the boiler. A large pulley at one end of the shaft receives its motion from a suitable motor. The materials are charged through the man-hole, and at the end of the operation withdrawn by a large valve at the bottom of the boiler.—H.

CAOUTCHOUC.—The qualities of sulphurized caoutchouc are described in column 2, page 448, vol. 1:—Allowing the chemical composition of caoutchouc to be $C_8 H_7$, the formula of the best vulcanized rubber ear-springs is found to be very near—



R signifying one equivalent of rubber= $C_8 H_7$. If rubber was represented by $C_{64} H_{56}$ —or eight times its present equivalent—the vulcanized ear-springs would have the compact formula:—



CIDER.—At page 475, middle of column 2, it is stated that in warm seasons it is still a desideratum to discover some means of checking a too rapid fermentation of cider. The process for the prevention of fermentation in saccharine solutions, denominated *mutisme* by the French, may be very easily applied for effecting this purpose. By adding to fermenting powder from one six hundredth to one thousandth of neutral sulphite of lime, or of bisulphite of soda, the fermentation may be reduced to a minimum, or entirely checked.

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